PROCEEDINGS

OF THE

ROYAL SOCIETY

OF

QUEENSLAND

FOR 1927.

VOL. XXXIX.

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Vol. XXXIX. No. 1.

Proceedings of the Royal Society of Queensland.

Presidential Address.

By J. V. Duhig, M.B.

(*Delivered before the Royal Society of Queensland, 4th April,* 1927.)

Before delivering my Presidential address, I want to say that good work was done by the Society this year, not only from the point of view of publishing scientific papers, but in supporting various objects of social as well as scientific bearing, such as the protection of our native flora and fauna and the establishment of reserves.

During the year we lost by death three of our members.

Mr. Charles Hedley, a Foundation Member of the Society, was later a Corresponding Member and a frequent contributor to its Proceedings.

Mr. R. H. Roe was a Trustee and well known to three generations for his scholarship and deep and cultured interest in education.

The Hon. A. J. Thynne was also a Trustee of the Society, Chancellor of the University of Queensland, and the promoter and earnest assistant of all sociological or scientific movements of value to the community.

To the relatives of these gentlemen, I offer the sympathies of the Society and my personal regret for their loss.

* * * * * *

NUTRITION.

It is now my pleasant duty to deliver to the members of the Royal Society the address which it is customary to expect from its President at the time when he retires from that office. To that office I had little pretension. I have done little active creative work beyond the organisation, as far as I could, of pathological and biochemical work on proper lines here. All pretension I possess is an enthusiasm for science as a creative force and as a directive force for the finer ambitions and energies of mankind.

The year that has passed has been extraordinarily fruitful for this Society in so far as the achievement of its active members is concerned. The annual volume of the Proceedings contains a huge amount of original work which would be creditable to any scientific society of similar size. But outside of this actual work done by our scientists, I confess myself a little disappointed at the progress the Society makes. Public interest in our meetings and in the work we do, public interest generally in science, is not at all what it should be. The Society has a small membership and a very precarious financial existence. To place before the scientific fellowship of the world in printed form the work we have done all but exhausts the whole of the financial resources at our command. It is very strange this should be so, since anybody who takes the trouble to inquire even into the history of scientific thought and method, and still more into that of any particular discovery or generalisation of economic value, is immediately struck by the peculiar beauty—one might almost say, the romantic beauty—of the process that greatly transcends the pleasure derived by the average person from participation in the every-day events of his life. I say nothing of the pleasure to be derived from actual scientific pursuits, but merely comment on the curious indifference of the large mass of people to those pursuits which are specially designed to make them happier and more comfortable.

Apart altogether from the lack of a training proper to promote interest in science, the fundamental reason for that indifference must be that the appeal of science is based on reason and no appeal is made to the primitive instinct of superstition in man, though one cannot altogether neglect to take account of the instinct of wonder, childish perhaps, at the gigantic natural forces about us and at the efforts we make to reduce the theory of their processes to something like order. But it still remains true that man generally prefers to be impressed rather than convinced. Man to-day is still living in the world of myth and guesswork that formed his mental concept thousands of years ago, and quackery and charlatanism flourish ; he appeals to magic rather than to science, heeding not that science is magic, that it has come to us through the hands of those who in a long line throw back to the alchemist and the weaver of spells. But so indelibly impressed is the mind of man with his littleness and his weakness amidst the forces that of old made him afraid, that now instinctively he seeks escape into the fairy world by contriving another world out of his imagination disordered by fear and so unfit for rational thinking. In that new world of his own contriving there is naturally no place for truth, and in any case truth is so small a thing, so patchy, so disparate now that it cannot in any sense explain the whole universe and man's relationship to it.

It was the fashion for the metaphysicians to attempt to do that, to view the universe as a whole and to erect a system of philosophy upon the concepts based on that universal view. In our present state that is impossible. Since Galileo, Bacon, and Newton, we have come to learn that the whole truth about life and nature is to be arrived at only by an almost infinitely long and laborious process. But another thing we have learnt is that the knowledge, partial as it is in relation to the whole problem, is a corpus of approximations so near the truth about special phases of the problem that we can be reasonably certain that eventually we shall have the whole truth. That is a pretty fine achievement, to be able to say that within the boundaries of our senses—that is, within our own natural limitations and by the touchstone of those senses which are, after all, the only criteria we have—the validity of our methods, ever being refined, is sufficiently cogent to put us in possession of the absolute truth of things. Though science enters into every phase of our existence, there does not seem to be any spontaneous recognition of the fact. Behind the cinema, and wireless telephony, and maid-less homes, and modern motor cars and aeroplanes, there is a vast field of research, and beneath it a mine of facts out of which the correlations of relevant and significant phenomena are brought up to the light by scientific workers. The cinema alone, which has so often been turned to base uses and from which so much wealth has been drawn, is the result of a long and patient effort embodying the efforts of courtless generations of physicists, lens-makers, photographers, chemists, engineers, electricians, mechanics, opticians, not to speak of artists in colour, form, and words. And this form of human effort is only a very small and as yet far from serious factor in human welfare. It is small and unimportant because the natural philosophy embodied in it has been diverted by heedless minds into a channel which forks one way to supply wealth to those who are ignorant of all the work that brought it into being and for which they know they cannot be expected to pay, and the other way to drug minds living in a dream world completely out of touch with reality. There seems, then, to be a definite cleavage between life as it is generally lived and science as it is understood by a small minority to mean truth. And there is thus precisely a cleavage between what is commonly called morals and the truths of science, between laws and customs and the whole methods of living and science. It is a cleavage between parties, one of which acts according to the mass suggestion that what the mob does is right, because it is comfortable and not contrary to generally-accepted opinion, and the other by reason and the known truth.

Majority rule is the essence of our present moral or social laws, irrespective of whether the laws are based on fundamentally sound natural assumptions. But since all progress naturally presupposes an intelligent minority holding views greatly in advance of those usually accepted at any given time, we must then agree either to outlaw the intelligent minority or forsake as obsolete the opinions of the unintelligent majority. Once we accept the idea of progress as the inherent end of human thought, we must agree to concede the inherent falsity of our present standards in whole or in part. In other words, if we agree to advance we must at once consent to abandon our old positions. To put it broadly, if we believe that the world is flat we are bound to provide some explanation other than the present one of the diurnal variation of light and of the tides and of the annual variation of temperature at a given part of the earth's crust. In other words, we cannot be static. It must be laid down that social conditions and thought about them are not definitely and finally set in a permanent arrangement. Most people act and think as if they are.

That this cleavage between science and common life exists must be abundantly clear, though it should not so exist. I know, myself, that a large amount of disease is preventible now, and how to set about the problem of prevention is clear and available ; but by a common failing of democracy, fear of responsibility, we do not use the right methods but give the people in these matters what they think they have a right to expect. For instance, a common method of preventing communicable disease now in use is fumigation, as curious a mythological survival as our quaint burial customs.

So wide is the cleavage that now scientists work quite independently of governments and newspapers ; that is to say, scientists generally have lost sight of any possible economic bearing of their work as their primary object, and then political methods are so empirical as to be useless to them, so that science has come to be a thing apart from common life in a most regrettable way.

Scientists have their own newspapers, written in an idiom incomprehensible to the ordinary man. But this local independence is only a part of a large international fellowship of independence which has broken down all frontiers and made the parochialism of the patriot quite a trivial thing.

But insensibly as science widens its frontiers of knowledge it will widen the people's mental horizon, and with that the boundaries of world fellowship. I have often heard it suggested that we have made no advances in our philosophical concepts or attitudes since ancient times. That cannot be true. Through science we have steadily grown in knowledge of what our outlook on the universe should be, and through it have made a vast multitude of social readjustments that we know were necessary. Science has given to life a fine dignity and has erected more and more rigid standards of the value and use of life. With all their ideals and all their knowledge the ancients were cruel : slavery and torture were part of the social system down almost to our own day. Now we know or ought to know that frequently crime and insanity are the fault of an imperfect social system and that man is not inherently bad. We are all kinder now in a physical way, if not quite so gentle with differing opinion or radical opinion. But political and religious intolerance will insensibly disappear as science brings to light new correlations of facts which explain parties one to another and make an adjustment possible. Except in Tennessee and a few other barbarous places, one is no longer compelled to display public abhorrence of a disbelief in the historical accuracy of the book of Genesis. Geologists, anthropologists, and zoologists have made such an attitude ridiculous. Such adjustments as that are of infinite value to the race, apart altogether from the physical comfort and well-being the scientist can command for us. So that I am more than a little dismayed at the common indifference to science, which after all stands for truth unalloyed and is the most rigidly honest system of philosophy mankind has ever evolved, besides which it teaches a large tolerance of honest difference of opinion.

The part played by science, then, in human affairs is an essential one, and indeed it is evidently fundamental to right living.

One aspect of the problem of life I shall now go on to discuss as the major portion of this address, and that is the principles on which we should proceed to maintain the life and growth of the human organism in a state normal foı the species ; that is, I shall discuss shortly what we now know to be the minimum demands of nature for the foodstuffs of the right quality and quantity necessary to bring the organism to the normal structure and function of the average specimen of the human species. The evidence for the facts has been arrived at in an indirect way, and most of the experimental work has necessarily had to be done upon laboratory animals, but certain contributing evidence from observation of humans makes it likely that these experimental data are applicable to humans.

The nutrition of the body is dependent on two factors—food of a certain quality and a certain quantity supplied through the digestive tract, and a supply of air by the respiratory tract for the oxidation of the food end-products. Thus there are two factors concerned—digestion and metabolism. With the latter I am not so much now concerned, as only in comparatively rare instances in proportion to the mass of material studied is oxidation ever at fault. Disturbance of endocrine balance and qualitative or quantitative changes in the circulatory system may affect oxidation to a marked degree, but the changes are pathological and do not affect the main issue I am to discuss, viz., What is the ideal diet ?

The digestive system of man has evolved into a tube of very great length in proportion to the height of the organism, having at its cranial end a mechanism for crushing food into a finely divided state, while below that a system of dilution and chemical change puts the food into a state necessary for absorption and oxidation. A certain residue of food is not absorbed, but for all that it serves a definite purpose in the digestive process.

Now these are clear simple evolutionary facts.

It is quite evident that primitive man, and indeed all mammalians at least, must have originally subsisted on a diet which needed pretty hard mastication to start with and which took some considerable time and effort to absorb, and which also needed a rough indigestible residue to start and maintain the wave that passed the food downwards along the tract. And we presume that must have been so, since agriculture is a pursuit of quite recent invention, and we are forced to the conclusion that man the hunter must have lived on meat and such vegetable growth as lay to his hand, rough or coarse, on account of their high cellulose content. We are pretty safe in assuming that the digestive tract of modern man differs very slightly, if at all, from that of Neanderthal or Cro-Magnon man, but civilised agricultural man is putting this system to uses quite other than were originally intended. Man is now unconsciously conducting a gigantic experiment in nutrition and out of it there can come only two alternatives. Either he must get back to a dietary which is comparable in its effects and demands on the digestive tract to those of primitive time, or consciously modify his evolved structure to meet new demands, as Bernard Shaw suggests as a possibility in his diverting preface to "Back to Methusalah." I for one will not be a subject of such an experiment as the latter alternative suggests. Now we must keep in view these nutritional demands of our structure when we discuss what is to be the ideal dietary.

It has long been known to physiologists that certain proximate principles are necessary in a dietary—protein, carbohydrate, and fat, as well as mineral salts which are incidentally present in the foodstuffs which contain those principles. We know also what proportions of these principles are necessary to a well-balanced diet and the total quantity of all three necessary to maintain in health a subject of given sex, age, height, and weight. And yet we can make up a diet on these lines, properly balanced chemically and generous in amount, on which not only the subject will not thrive but actually become subject to disease. It is upon a diet of this sort that quite a large part of the race is attempting to subsist.

We now know that in addition to chemical balance other factors are necessary to make the foodstuffs available for maintenance, growth, and warmth. The experimental work upon these accessory food factors or vitamins has thrown a flood of light upon what were obscure deficiencies of growth and structure. That these substances must exist in an efficient dietary can be abundantly proved by removing from the food of an experimental animal certain constituents.

The animal fails to thrive or may even acquire disease, but the failure and the disease may be prevented by restoring these constituents to the dietary. That is the experimental method on which we base our knowledge of the existence of those accessory factors. Of old it was hard for pathologists to associate disease with the absence of some positive agent, and so the physiology and pathology of nutrition were imperfectly understood, even when Eijkmann established the connection between beri-beri and the use of decorticated rice. He suggested that the cortical substance was needed to neutralise an excess of starch in the grain. But his work started a train of investigation which established once for all that the absence of certain factors acting not necessarily quantitatively but probably as catalysts in metabolism produces disease. The danger of deficiency diseases, so called, to a community, is not great where an abundant supply of natural foods is available if that supply is used in the right way. But it does exist very particularly in communities relying on a food supply restricted in range. But even in communities where the natural food supply is varied and ample it is customary to estimate nutritional requirements on a basis of protein, carbohydrate, fat, and inorganic salts required. The fallacy of this I shall show later on. I want here to digress a little and discuss briefly the question as to whether the quality of each of these so-called fundamental principles is material to the issue apart from the vitamin content of the food.

First, as to the sort of *protein* used. The foods used by most communities will provide the protein whose animo-acids are of the best quality for tissue maintenance. McCollum, Simmonds, and Parsons made experiments "to determine the extent to which any protein or mixture of proteins falls short of the best quality yet observed." They conclude, "Kidney, liver, and milk proteins stand out as a group of foods containing proteins of unusual value. Among the cereals wheat stands first in the quality of its proteins. Without exception it has been found that two cereal grains fail to supplement very well the protein deficiencies of one another, and accordingly animals do little or no better when fed 9 per cent. of protein served from two cereals than they do confined to one. On the other hand, there are some remarkable instances of supplementing action between certain cereal grains and legume seeds. Conspicuous among these successful combinations is wheat and pea. Maize and pea in combination proved almost a failure for the nutrition of the rat." So that where glandular organs used as meat and milk are absent from the food supply, care must be taken to supplement it with combinations of vegetable porteins of good quality, such as wheat and legumes.

The Quantitative Physiological Requirement of Protein.—The evidence on this point is somewhat conflicting. It was formerly held by Chittenden (1904 and 1907) and Benedict (1906) that a low protein intake, such as is necessary to just more than maintain nitrogen equilibrium, produces no change in the normal process of growth and tissue repair, but McCollum has come to the conclusion that "when the life history of the individual is considered, a generous protein ingestion or one allowing a fair margin of safety over the lowest percentage which just suffices to induce maximal growth in the young serves to maintain vigour for the longest possible period."

Against this view were the data of numerous workers who considered that a high protein diet tended to have a certain effect on renal function. In reviewing the literature for the past year I find two papers of interest in this connection.

McLean, Smith, and Urquhart (B. J. Exptl. Path. VII. 6, 360) worked with rabbits, which are normally herbivorous and do not consume very much protein food. This aspect of the question was taken up independently by Jackson, whose work we shall review shortly. But it is to be noted that an unknown factor is introduced, as McLean notes. He and his co-workers fed to rabbits a normal diet consisting of protein 11·5 per cent., carbohydrates 60 per ceent., and including fresh cabbage. The range of blood urea variation over a period of twelve months in six animals was from 22 mg.–50 mg. per 100 cc.

On a diet consisting of 60 per cent. protein and green food the animals immediately showed a high blood urea content and a correspondingly high urine concentration, but within a month these readings both fell to normal. There was not at any time any albumen or casts in the urine. But when a high protein diet was fed without green food, nephritis developed, the period of its appearance varying with certain factors, as exposure to sunlight. The same effect is produced by a normal diet without green food.

These workers summarise their results as follows :—

> " High protein feeding when accompanied by a little green food produces temporary changes in the metabolism of the rabbit indicated by a rise in the blood and urine urea . . . The renal mechanism apparently adjusts itself to the increased nitrogen intake, so that examination of both blood and urine for nitrogenous waste gives normal results.
>
> " A very high protein diet, when a little green food is given, does not give rise to any changes of the nature of nephritis in the rabbit's kidney. The absence of green food, however, very soon results in nephritis, no matter what the protein content of the diet happens to be."

It is difficult to evaluate these findings, but one point seems clear, that high protein feeding of a diet normal to the species does not produce marked metabolic disturbance over a period long in relation to the life of the animal.

Jackson and Riggs (Jl. Biol. Chem. 1926, LXVII. No. 1) used rats, which are normally high protein feeders and are not normally as subject to spontaneous renal disease as rabbits. These workers used two diets, each containing as high as 76 per cent. protein, and conclude that—

> " By feeding very high protein diets over a period of 10 to 20 months, or about one-third of a rat's life, we have been unable to produce in these animals any recognisable nephritis."

So far, then, as the evidence goes, we are right in assuming that even in animals unaccustomed to food which contains a large amount of protein no disturbance other than a temporary one of metabolism occurs, and in animals accustomed to high protein diets no disturbance occurs of any kind. Man is a high protein consumer and, provided we make allowance for whatever error is inherent in the work of McLean and his co-workers by the selection of an animal whose nutritional demands introduce an inestimable nutritional factor (a possible error which may have very interesting bearings on the general question fo protein metabolism in relation to calcium or vitamin D as the green food and sunlight factors suggest), we can with safety recommend a diet rich in protein, a very desirable thing where tissue waste is at a maximum, as in hard manual labour. If the safety factor as indicated by McLean's experiments is a substance of high vitamin content that would indicate a return to something more closely resembling the primitive dietary which I propose to recommend, *e.g.*, liver meat, would be preferable to casein as a source of animo-acid.

Carbohydrates.—These are the proximate principles which form the basis of what I call our gigantic experiment in nutrition. The particular substances which now provide the bulk of the carbohydrate fraction of human dietary are refined cereals, principally white wheaten flour and polished decorticated rice and refined sugar—cane or beet. Apart from the absence from these substances of vitamin of any kind, their claim on other grounds to be considered suitable components of a dietary must be very carefully weighed. Either alone or combined these substances provide a large proportion of the modern dietary—white bread, scones, biscuits, cakes, pastry, and confectionery of all sorts. These things require little or no mastication, they are very quickly absorbed, and leave no residue. Thus is the evolution of the digestive tract rendered quite futile. It is curious that no other substances of diet create such a taste—one may fitly say, such a craving—as these refined carbohydrates. It would be presumptuous to observe that they are dietetically injurious, since we do not know precisely what the trend of our evolution is to be. If we are to be edentulous and reduce our digestive tract to a mere vestige, the consumption of refined sugar and cereals is the surest way to that end. Let me review again the carbohydrate content of the diet of primitive man and contrast it with that of the moderns. For carbohydrates primitive man had to depend upon vegetables, fruits, meat, milk, and possibly honey. That series contained all the starch he could possibly get, and indeed that condition of things persisted right down into comparatively modern times. And it is to be noted that nature provides for the suckling a food of comparatively low carbohydrate content. Modern man eats flour and refined sugar. This consumption of refined cereals and sugar is what I term our gigantic experiment in nutrition. Not only is agriculture, the culture of cereals, a comparatively modern pursuit, of very short duration in comparison to the tens of thousands of years man has spent on earth, but milling methods are actually very recent indeed. Incidentally western milling methods were entirely responsible for beri-beri in the Asian countries where rice is the staple, and is now responsible for the huge amount of diabetes prevalent in these rice-eating communities. It is in respect of this disease that this experiment is so fraught with perilous possibilities. Allen has shown very clearly that the pancreas which supplies the hormone specifically concerned in the katabolism of glucose is capable of exhaustion by repeated large doses of glucose. He fed to partially depancreatised dogs such small quantities of glucose as were necessary to provide for normal energy output, without, as he observed, producing any further degeneration of the pancreas. But when the system was flooded with more glucose than the remaining pancreas could deal with, not only did symptoms of hyperglycæmia and glycosuria supervene but the pancreas itself underwent degeneration. Now, whether excessive carbohydrate intake is a cause or a symptom of diabetes, from the experiment of Allen's and from what may generally be observed there does seem to be involved another factor in pancreatic exhaustion besides the mere quantitative value of glucose ingestion. This factor seems to be the rate of assimilation, since diabetics will assimilate without symptoms their maximum ration of carbohydrate provided in the form of fruit and vegetables, though they cannot do it when they are fed white bread, potatoes, and rice. This would seem to depend upon the *rate* of assimilation and oxidation, which is slower in the case of carbohydrates of different kinds such as levulose, bound up with other substances in vegetables, than is the case with the pure starch or sugar of flour, potatoes, or refined sugar. The carbohydrate necessary in a diet would seem to me then to be such as may be slowly assimilated and relatively low in quantity. The carbohydrate fraction of the modern dietary depends so much upon its vitamin content, however, that we shall return to the subject again in discussing these accessory factors.

I have thought it necessary to discuss these principles of dietary in a specially quantitative way to clear the ground for a discussion of their vitamin content.

A considerable literature has accumulated on the vitamins, and as it would be impossible to traverse that, I shall confine myself, first to a general summary of our knowledge of the subject with special reference to certain nutritional problems likely to arise in a community such as ours, and then to a discussion of what should be the ideal dietary for such a community.

Our knowledge of the subject of vitamins is really of long date and starts from certain empirical observations on nutritional disturbance we now know to be due to vitamin deficiency. Captain Cook, for instance, was well aware of the beneficial effect of the juice of citrus fruits in the prevention of scurvy, and I have already spoken of the association noted by Eijkmann between beri-beri and decorticated rice. It was noted as long ago as 1881 by Lewin that artificial mixtures of proteins, carbohydrates, and fats, along with inorganic salts and water, are not adequate for rearing young animals, whereas milk will suffice. It contains all these principles, so Lewin concluded there was some other factor involved in growth and maintenance than just these. Gowland Hopkins definitely established the fact (Jl. Physiol. 1914, 44, 425). He fed to two sets of male rats a diet as follows :—

1. A diet consisting of purified casein, starch, lard, inorganic salts, and water.
2. The same, with 3 cc. of milk in addition.

Rats fed on the first diet failed to gain weight at anything like the same rate as those fed on the second, and the discrepancy could not be accounted for by the amount of solid matter contained in 3 cc. of milk. But when the first set of rats were given the milk their growth increased at an extraordinary rate, while the second set deprived of the milk remained stationary and then slowly declined. This experiment established definitely the presence of a growth-promoting factor, while the earlier work noted pointed to the necessity for the presence of certain specific substances to prevent beri-beri and scurvy.

The vitamin or specific factor indicated by Gowland Hopkins's work as necessary to the growth of young animals being always found in association with fats was referred to as fat-soluble vitamin and then as vitamin A, the anti-neuritic as vitamin B, and the anti-scorbutic as vitamin C, the two latter being water soluble. Recent work, some of which I shall now proceed to review, has definitely shown that in addition to the growth-promoting substance of Hopkins, fat soluble vitamin is also concerned in bone and tooth formation and with the prevention of sterility. The two latter factors are now known to exist as definite entities apart from vitamin A and are known respectively as vitamin D and vitamin E. It is to vitamin D that I shall address particular attention.

Before doing so, I want to say that as it is impossible to include within the limits of this address a complete list of the vitamin contents of foodstuffs, I must refer you to the medical Research Council pamphlet " On the present state of knowledge of accessory food factors (vitamins) " 2nd Edition 1924 which gives a comprehensive and pretty complete list in respect of vitamins A, B, and C. It is sufficient to say that vitamin A is present in abundance in butter-fat, fish-liver, fats, milk, to a less extent in other animal fats, and is absent from lard, olive oil, and margarine, derived from vegetable oils or lard. This confirms the value of the empirical use of cod-liver oil in tuberculosis in preference to vegetable oils. It is absent from white flour and oatmeal. It is fairly plentiful in fresh green vegetables, but low in raw potatoes. Vitamin B is plentiful in all milk and fresh green vegetables, but low in cooked potatoes and absent from decorticated grains and white flour. Vitamin C is associated mostly with fresh green vegetables and fruit. It is present in milk whole, almost absent from pasteurised, and completely absent from sterilised or condensed milk. It does not stand keeping. It is quite apparent then that fruit and green vegetables are potent sources of these important food factors and indeed careful experiments have shown that animals are absolutely dependent on vegetable sources for their vitamin supply. The vitamins of milk-fat have been traced to green fodder, and Drummond and Zilva (1924) have traced the vitamin A of cod-liver oil back to vegetable diatoms. This fact has a most important bearing, naturally, on the ideal human dietary.

In a community such as ours, beri-beri and scurvy are rare owing to the wide distribution of the vitamins necessary to prevent them. But such is not so with those diseases involved in the absence of fat-soluble vitamins A, D, and E, since their range in the food supply is necessarily limited, and this has a serious bearing on the nutrition of infants. In mother's milk Nature has evolved a perfect food for promoting growth. The milk normal to the species is naturally the perfect food, and a relationship has been established between the chemical composition of the species type of milk, and the normal rate of growth, but protein and mineral salts alone will not produce growth without accessory factors. Further the vitamins of milk seem to be a definitely quantitative function of growth rates. Osborne and Mendel (1918) have shown, for instance, that cow's milk may be an inadequate source of vitamin B for the rat. So that the ideal diet for the growing child is at first its own mother's milk. But as I mentioned above, animals are dependent on outside sources for their vitamins, the cow for her fat-soluble A on green pastures, so that pregnant and nursing mothers need a diet high in vitamins if they are to produce infants with a normal growth impulse and to rear them at the normal rate of growth. The most important factor in the infant's dietary is fat-soluble vitamin A, so that if breast feeding is discontinued cod-liver oil should be added to the diet.

Proprietary foods as a rule are deficient in fat. If dried feeds are used or foods subjected to heat, anti-scorbutic water-soluble C should be supplied in the form of fresh fruit juice. The question of inorganic (mineral) salts I shall discuss at more length.

Vitamin D.—It is the absence of this vitamin from dietaries, along with deficiency of the minerals, or with the metabolism of which it seems bound up, which has produced so much skeletal and dental deformity. The name is now used to indicate the anti-rachitic vitamin present especially in cod-liver oil and in other animal fats, but capable of differentiation from vitamin A. Cod-liver oil, for instance, loses its vitamin A after oxidation at high temperatures, but not the anti-rachitic factor. Also butter is more potent in vitamin A but less in vitamin D than cod-liver oil.

Luce (Biochem. Jl., 1924) observed also that if a cow receiving a diet deficient in fat-soluble vitamins is exposed to strong sunlight, the growth-promoting properties of the milk are only slightly affected, whereas the anti-rachitic value of the milk is markedly increased. It is upon experimental rickets in laboratory birds and animals that most of our knowledge of this vitamin is based. Rickets is a disease which varies considerably in different species, but the essential feature seems to be a disturbance of calcium and phosphorus metabolism such that there is a deficient deposition of calcium salts, chiefly calcium phosphate, which results in lack of rigidity of the bones, and deformity. Histologically there is a lack of calcification of the membranous and cartilaginous matrix of the bone. It has been possible to produce rickets in laboratory animals on a diet so adjusted that the deciding factor as to its production becomes the presence or absence of vitamin D, which is mostly derived from cod-liver oil. It is obvious also that since rickets depends on imperfect calcification or, more strictly, on the calcium $\times$ phosphorus product, the absence or deficiency of these elements will aggravate the condition, so that a rachitic condition will be produced most speedily by simultaneous deprivation of both anti-rachitic vitamin and calcium and phosphorus. A third factor is concerned in the production of rickets, viz., light.

The effect of light in this connection is summarised by the Medical Research Council Committee (1924) as follows :—

1. The bone lesions of infantile rickets have been cured by exposure of the patient to the radiation from a mercury vapour lamp or to direct sunlight.

2. Exposure to direct sunlight or to the radiation of an arc lamp or mercury vapour quantity lamp prevents the development of rickets in experimental animals on diets on which control animals kept in darkness or diffused light acquire the disease.

3. The active radiation is confined to the ultra violet rays of $\lambda = 300\mu\mu$ or less.

4. These radiations also stimulate the growth of young rats on diet deficient in vitamin A. After about eight weeks, however, growth is checked.

5. The radiation probably acts by mobilising the reserves of the fat-soluble vitamins in the body.

The effect of sunlight is interesting and comforting to inhabitants of this country, since it has been observed also that rats on a rachitic diet containing twice the optimal amount of calcium but deficient in vitamin D and phosphorus do not develop rickets if exposed to sunlight. It seems that light will mobilise the phosphorus whenever available. But it must be recognised that (1) the vitamin D is prepotent in the prevention of rickets, and (2) ultra-violet light will correct partial but not absolute deficiency of dietetic factors necessary for ossification. An interesting development has been that the anti-rachitic property can be conferred upon foodstuffs otherwise lacking it by irradiation with ultra-violet light, as casein, dried milk, flour, olive oil, lettuce, and spinach, which though rich in calcium contain little if any vitamin D, but by irradiation may act as if they do. This power to acquire vitamin D properties seemed to have been related to the content in sterols notably cholesterol and phytosterol. Very recent work, of which advance notice has been given in this country but of which no details are yet available, make it clear that the activating agent of bone formation in these substances is bound up with a fraction of the sterol molecule.

We again summarise the role of vitamin D as follows (M. R. C. Committee, 1924) :—

1. An anti-rachitic vitamin in the diet corrects improper balance in the calcium and phosphorus intake, and the greater the disproportion or defect in these elements the more important is the role of the vitamin in the prevention of rickets.

2. Even when the calcium and phosphorus balance is good and the supply of each is adequate, the absence of anti-rachitic vitamin from the diet will result in the production of imperfectly calcified bone.

To which we may add—

3. That direct sunlight or the use of irradiated sterols may partially compensate for the absence of vitamin D.

An interesting sidelight on the relation of the blood calcium and phosphorus product to fat-soluble D is provided by a recent paper of Hughes and Titus (Jl. Biol. Chem. 1926 LXIX., No. 2) on "Leg weakness in chicks." These authors correlate the presence of leg weakness with a calcium and phosphorus product and the presence or absence of an anti-rachitic factor, whether a foodstuff actually containing the anti-rachitic factor, or light radiations.

These authors attempted to show that leg weakness in chicks was analogous to rickets in man, and conclude that "the preponderance of evidence indicates that the etiology of leg weakness in chicks and rickets in mammals is the same." But for me, far the most important aspect of this paper is the fact that all presumptions I entertained about vitamin D are confirmed. Howland and Kramer have shown that the incidence of rickets varies directly as the product of the calcium and phosphorus contents of the blood. They state that when the product is below 30, rickets is to be expected ; between 30 and 40 it is probable. When the product is above 40, either healing is taking place or rickets is entirely absent.

In Hughes and Titus's series the highest calcium and phosphorus product occurred in chicks fed with irradiated milk, and in no case did the product fall below 40 when there was either an adequate supply of anti-rachitic factor or of direct ultra-violet light. Where the anti-rachitic vitamin was deficient, leg weakness developed and the calcium and phosphorus product was on the average considerably under 40. Non-irradiated milk from cows on winter pasture, *i.e.*, cows feeding on pastures and enjoying a relatively reduced exposure to sunlight, was not potent enough to bring the calcium and phosphorus product over 40, and leg weakness developed in chicks placed on this ration. Whether we accept or not Howland and Kramer's formula as a valid assumption of fact, it remains that ossification and calcification generally depend on proper adjustment of intake of vitamin D, calcium and phosphorus, the effect of their interaction being complete if ultra-violet light is available. Further research will probably tend to prove that light is only a partial substitute for vitamin D in the sense that once all of the vitamin is exhausted within the tissues and no more is available from without, light alone will not prevent the characteristic signs of vitamin D deficiency.

While the credit of establishing this factor as definite entity must go to McCollum and his co-workers, it must be said that the earlier researches of Mellanby pointed to this probability. But the earlier work of Mellanby was inconclusive, since he attributed certain effects to a positive factor, in this case, oatmeal, when these effects could quite legitimately be attributed to a deficiency.

In a recent article (Biochem. Jl. xx., 5, 1926), Mrs. Mellanby and Miss Killick have undertaken a further overhaul of the subject of calcification processes, including that of tooth decay.

Their preliminary study, recently published, sets out the problem as it then existed. Since tooth structure and position is essentially a function of calcium metabolism, investigation of vitamin D was extended to embrace these factors in human nutrition.

Since the first report of Professor Mellanby in experimental rickets, and arising out of that work, research has been undertaken by Mrs. Mellanby into "the factors influencing the development of teeth and jaws in puppies and other animals, with the object of attempting to discover the main causes of the bad teeth of civilised nations." The work was extended to children in two ways.

Mrs. Mellanby summarises her findings :—

1. A large number of deciduous teeth of children have been examined, and it was found—

(*a*) That they were badly calcified to the extent of 80 per cent.; not 30 per cent. as usually stated.

(*b*) That there is a direct relationship between structure and caries—in general the worse the structure the more the caries.

(*c*) That, when teeth are well calcified and yet carious, their resistance after eruption must have been poor, as evidenced by the badly formed or deficient secondary dentine, and *vice versa*. When teeth are badly formed and yet non-carious, the secondary dentine is abundant and well calcified, indicating good resistance.

2. On the basis of the above results, Mellanby, Pattison, and Proud (B. M. J. 1924) tested the effect of diet on the erupted teeth of children. They inferred :—

(*a*) That well and badly calcified teeth can be produced at will by altering in the diets the relative amounts of calcifying vitamin found in milk, egg yolk, cod-liver oil, &c., and anti-calcifying substances found chiefly in cereals.

(*b*) That the better calcified the teeth the less liable are they to be attacked by caries.

(*c*) That after eruption a calcifying diet tends to increase the resistance of the teeth, whatever their structure, to the onset and spread of caries.

These inferences may be justified, but require the crucial test of being deduced from experiments on animals in which experimental caries may be produced at will. As yet authentic caries has not been produced in the animal. Mrs. Mellanby's work is well planned and avoids the chance of fallacy inherent in the earlier researches of her husband. So far she has investigated cod-liver oil, egg yolk, green foods—as grass and cabbage and root crops—turnips, swede turnip, and carrot, added to a basal diet of oats, bran, and salts.

Her findings are as follow :—

1. Diets are described which, while allowing good growth and good general health in rabbits, produce very defective calcification of teeth and bones. It is hoped by feeding these diets to produce ultimately dental caries.

2. The degree of abnormal calcification is related to the growth of the animal. If x grm. of a diet produces rickets, $2x$ grm. of the same diet will produce worse rickets.

3. The worst calcification is obtained in rabbits under the experimental conditions when the calcium and phosphorus content of the diet approaches figures which have been described by workers on rickets in rats as likely to prevent the disease.

4. Calcification in rabbits responds immediately, in the same way as in other animals studied, to an increase in calcifying vitamin in the diet and to exposure either of the animal or food to ultra-violet light.

5. Examination of some vegetable foods indicates that they are for the most part deficient in calcifying vitamin. Grass' especially summer-grown grass, contains more than cabbage. Of the root vegetables, carrot and swede turnip contain more than white turnip.

These workers throw doubt on the validity of the calcium and phosphorus ratio or the absolute content of each element in the diet as an essential or even important factor in calcification. They state :—"It may be said with some certainty that if there is abundant anti-rachitic vitamin in the food, the question of calcium and phosphorus is negligible and that even the absolute amounts of calcium and phosphorus in the diet so far as ordinary foods are concerned are of small importance." That is, of course, only so far as calcification of bones or teeth is concerned.

So far and experimentally the question of dental caries, both in its general aspect or its relationship to diet, is not solved. Some light may be indirectly put on it by an appeal made to surveys of dental condition as it exists for peoples living in various dietaries more or less standardised by custom and limited availability both as to quantity and range. The teeth of certain civilised communities, especially those of the bulk of the people of the North American continent, are strikingly defective from the point of view of structure, position, and resistance to decay. The teeth of Australians are not much better. These communities are living in the era of agriculture and refined milling methods. It would be rash to assert a causal relationship between these facts. But it is nevertheless interesting to compare the dentition of people who have lived before our dietary conditions became operative or are now living outside them.

McCollum and Simmonds observe that an examination of prehistoric and pre-agricultural teeth shows that there probably was no period in human history when people were free from toothache and dental caries and generally imperfect dentition, but where any sort of valid evidence is available it is found that perfect dentition existed amongst people living on natural uncooked food of wide range, while such people as the Egyptian aristocrats of predynastic and protodynastic times, and primitive Hawaiians, had bad teeth, attributed to the use of soft cooked luxurious food of very narrow range. The staple of the Hawaiians was cooked taro.

The Icelanders afford an interesting comparison between peoples living first outside and then within the conditions of dietary as we know them to-day.

From the settlement in the ninth century down to about 1850 the diet consisted mainly of fish and butter, there being no grain on the island and imported bread being unknown. But by 1870 a remarkable change occurred. A traveller states that in 1873 "Cereals whose consumption ranges from 24–30 bushels a head are wheat, rye, in grain flour and biscuit." Again, "Besides cereals, the stores supply sugars, hams, sausages, and sardines, butter, figs, raisins, prunes, and olive oil." The health conditions were good and dental caries were unknown until after *circa* 1850. Stefansson exhumed ninety-six skulls from a cemetery dating from the ninth to the thirteenth centuries. They were described by Hooton, who found no evidences of caries in any of them. There were three or four defective teeth in the entire series, and these had suffered mechanical injury. During the last half-century the incidence of caries has increased greatly in Iceland. This corresponds closely with the changed conditions in respect of import of grain, and consequently change in character of diet.

Again, *Indians* of American plains had wonderful teeth. In 200 skulls excavated from cliff dwellings not a single carious tooth was found.

Italians.—Horne observed for many years the teeth of Italian immigrants to Boston. He found parents and children to have teeth far superior to those seen in America.

Again, a chance investigation of the teeth of the people of Tristan da Cunha was recently made by the medical officer of a ship carrying supplies to the island. Dental defects were extraordinarily rare. Their diet consists of meat, milk, eggs, butter, and vegetables. They are naturally denied the use of refined cereals and foods of high starch concentration.

As I say it would be rash to suggest any connection between modern dietary habits and tooth decay, but one cannot help noting the co-existence in U.S.A. of a vast and alluring publicity for sophisticated refined cereal breakfast foods with altogether excessive dental defects in the whole population, which have had the interesting result, I presume, of making that country pre-eminent in reparative technical dental science. I should think dentists would be badly equipped in northern rural Italy where they are not in any case needed.

Having traversed the most important developments in human nutrition, let us apply them to our present conditions.

An average household of to-day lives mainly on muscle meat, white bread or articles made from white flour, tea with enough milk to colour it, cane or beet sugar, potatoes, sweets—principally a sugar paste covered with chocolate—eggs when they are not too expensive, butter or margarine, a little fruit very often imported and preserved in a viscous sugar syrup, and some vegetables.

Practically all these articles are cooked to a soft consistency, so that mastication is reduced to a minimum in defiance of evolutionary demands and of its corollary that development of a structure or organ depends on exercise of its function. The food that does not cling about the teeth is rapidly absorbed and leaves only a relatively slight residue. It is hard to escape a tentative correlation between such a diet and imperfect dentition and constipation, both of which are very prevalent.

Here set out is the vitamin content of such a diet :—

Food Constituent.	V–A.	V–B.	V–C.	V–D.	Ca %.	P.
White flour ..	Nil	Nil	Nil	Nil	0·026	+
Muscle meat ..	Nil	+	+ (low)	Nil	0·0038	+
Muscle meat, tinned	Nil	Nil	Nil	Nil	—	—
Tea	Nil	Nil	Nil	Nil	Nil	Nil
Milk (fresh) ..	++	+	+	++	0·12	+
Sugar	Nil	Nil	Nil	Nil	Nil	Nil
Potatoes (cooked)	? Nil	+	+	? Nil	0·011	+
Eggs—						
Yolk	+++	+++	Nil	+++	+	+
White	Nil	Nil	Nil	Nil	?	?
Butter	+++	Nil	Nil	+++	—	—
Margarine—						
From vegetable oils and lard..	Nil	—	—	Nil	—	—
From animal fat	+ to ++	—	—	+ to ++	—	—
Fruit—						
Raw	Nil to ++	+	+++	? Nil	—	—
Preserved ..	—	—	+ (low)	? Nil	—	—
Vegetables—						
Green ..	++	++	+++	+ (low)	—	—
Roots ..	Low to +	++	+ to ++	+ low	—	—
Milk—						
Dried	++	+	Nil to +	+	—	—
Condensed ..	++	+	Nil to +	+	—	—
Proprietary foods	+ (low)	+ (low)	Nil	+ (low)	Low	?
Jam	Nil	Nil	Nil	Nil	Nil	Nil
Honey	? Nil	+	Nil	? Nil	—	—
Olive Oil ..	Nil to +	Nil	Nil	? Nil	—	—

Other foods not so frequently used.

Food Constituent.	V–A.	V–B.	V–C.	V–D.	Ca %.	P.
Lard	Nil or low	—	—	—	—	—
Mutton fat ..	—	+ (low)	—	—	—	—
Custard powder ..	Nil	Nil	Nil	Nil	—	—
Oatmeal	Nil	—	Nil	Nil	—	—
Rice, polished ..	Nil	Nil	Nil	Nil	—	—
Whole grain ..	+	++	Nil	? +	—	—
Wheat—						
Whole grain ..	+	++	Nil	? +	—	—
Bran	+	++	Nil	? +	—	—
Peas, dried green	++	++	+	+	—	—
Nuts	Very low	++	—	Nil	—	—
Fish—						
Lean	Nil	Very low	—	—	—	—
Fat	++	Very low	—	—	—	—
Roe (cod) ..	+++	Very low	—	—	—	—
Meat—						
Tinned ..	—	Nil	Nil	—	—	—
Extract (beef tea)	—	Nil	Very low	—	—	—
Liver—						
Ox	++	+++	—	? ++	—	—
Pig	++	++	—	? ++	—	—
Kidney, pig ..	++	++	—	++	—	—
Starch	Nil	Nil	Nil	Nil	—	—

Nil = absent; + = present; ++ = in quantity; +++ = abundant.

It should now be easy to build up the ideal diet.

For Infants.—Milk from the mother who is herself on a diet suitable to fulfil all the required ideal conditions, since upon the pregnant mother the growth impulse and correct structure of the infant depend. In the absence of this diet, a natural milk. From milk the child gets all the protein, carbohydrate, fat, vitamin, mineral salts and most of the water it requires. Incidentally it may be mentioned that milk is the most potent source of calcium we have. It is useless adding limewater to a child's milk. McCollum has shown that even large quantities of calcium salts do not inhibit rickets. If thought necessary, cod-liver oil and lemon juice will help.

For the growing child the diet will be as for adults, with the precaution of abolishing from their diets white bread, cake, scones, biscuits, lollies, and ginger pop.

The biscuit advertisements are founded on the fallacy that the human dietary requires protein carbohydrate and fat in a "purified" form, *i.e.*, without vitamin.

The frequent meals of bread, butter, and jam or honey should be stopped, and children should be made to feel hunger and satisfy it at regular intervals well spaced.

For the adult, the ideal diet is one that requires hard mastication, leaving no residue in the mouth about the teeth, that it shall be absorbed relatively slowly, leave a rough residue in the digestive tract, shall contain a liberal protein fraction, a minimum starch fraction, and shall contain as high a vitamin content as possible, especially of the fat-soluble factors.

Such a diet would consist of glandular meats such as liver and kidney, a large amount of fresh milk from cows fed in green pastures in sunlight, wholemeal wheat bread, fresh butter, eggs, raw green vegetables, and fresh fruits. That is a working basis; it fulfils all requirements. Two of the articles required in this regimen are by a curious stroke of fate referred to as offals, viz., the internal organs of animals, and bran. I do not know what is here the consumption of fruit and vegetables per head, but I submit it might be higher. It is disheartening to see in shops good fruit boiled up to a pulp with sugar and sold as jam, and fruit canned abroad and actually imported into and consumed in a fruit-producing country.

It is hardly realised that sun-ripened fruit and green vegetables are necessary parts of a dietary, not incidentals or luxuries. To eat fried steak and potatoes, steamed "duff" and treacle, tea and bread and jam, is to use things that nature gives us for food in a misguided way, and for all the purposes of nutrition such a diet is practically useless.

Cookery is a fine art, and while in moderation we may enjoy the sweet and dainty things it provides, they should be supplemented by the raw products of nature.

We are only at the beginning of a new era in our understanding of the processes of nutrition, but even now right-living is infinitely easier than it was as late as twenty years ago. Soon deficiency diseases and those due to faulty nutrition will become extinct.

Flagellates in Certain Queensland Plants.

PRELIMINARY NOTES.

By Thos. L. Bancroft, M.B.

(*Read before the Royal Society of Queensland*, 2nd *May*, 1927.)

Trypanosomes have been known to occur in the milky juice of Euphorbiaceous plants since 1909, when Donovan suggested the name *Phytomonas* for them, and Lafont in Mauritius described the first species, *Phytomonas davidi*, found in the latex of *Euphorbia pilulifera*; since then others have been described. (*See* "Protozoology" by C. M. Wenyon.)

No one, so far as I know, has hitherto found Flagellates in Australian plants.

There is a species in the Asclepiadaceous plants *Sarcostemma australe* and *Hoya australis*, and a larger species in *Secomone elliptica*, and a different kind again in *Ficus scabra*.

There can be no doubt that many species await discovery in Australia, for out of a dozen plants with milky juice examined by me, four have been seen to harbour them. It is well known that insects take the role of intermediary host for *Phytomonas*. There is a bug (*Oncopeltus quadriguttatus*, Fabr.)* constantly in association with *Hoya australis*, living on the milky juice of the plant; it will also suck the juice of *Sarcostemma*.

I found Flagellates in the intestines of these bugs; a larger form than that in the juice of the plant, which is what occurs in respect of other species of *Phytomonas*, the life-histories of which have been worked out.

The dimensions of the *Phytomonas* found in *Hoya* and *Sarcostemma* are :—Body, $17\mu \times 2\mu$; flagellum, 18μ.

Trophonucleus situated considerably nearer the anterior end than centre of body.

* Identified by Mr. Anthony Musgrave. He remarks, however, that it is not quite typical.

A Revision of the Queensland Polygona.

By B. H. DANSER, Assistant at the Herbarium of the Botanic Gardens at Buitenzorg, Java.

(Text-figure 1.)

Communicated by C. T. White.

(*Read before the Royal Society of Queensland, 28th May, 1927*).

Introduction.

This revision is principally based upon the Polygona of the Queensland Herbarium of the Botanic Gardens at Brisbane, collected for the greater part and kindly put at my disposal by Mr. C. T. White, Government Botanist. I have, however, also mentioned some specimens from the National Herbarium at Melbourne, the State Herbarium at Leiden (Holland), and the Herbarium of the Botanic Gardens at Buitenzorg, respectively indicated as (H.M.), (H.L.B.), and (H.B.). This revision shows that up till now fifteen species have been collected in Queensland. Four of these (4, 9, 12, and 14) are new for this country. On the other hand three species (*P. lanigerum*, *P. subsessile* and *P. articulatum*), recorded for Queensland hitherto, have been united with other ones. Of the fifteen species mentioned by me, nine also occur in the Netherlands East Indies, and these have been dealt with more in detail in my revision of the Polygonaceæ of those regions [9]. Of the remaining six species, two (4 and 14) are also found in tropical Asia, two (1 and 15) have been introduced from the temperate regions of the northern hemisphere, and two (8 and 9) occur only in Australia and surrounding islands.

KEY TO THE SPECIES.

1. Flowers in clusters in the axils of normal leaves, not crowded into more composite inflorescences. Leaves small, at most 4 cm. long, broadest in or above the middle .. .. 2.
   Flowers in clusters, the clusters crowded into long or short leafless spikes, the spikes grouped or not into larger inflorescences. (Rarely the flowers in axillary clusters, but in that case the leaves are sagittate.) Leaves usually more than 4 cm. long, broadest in or below the middle .. .. .. 3.

2. Fruit shining, broadest near the middle, about 1 to 1½ mm. long. Leaves with invisible lateral nerves .. .. .. 2. *P. plebium.*
   Fruit dull because of minute longitudinal wrinkles, broadest in or below the middle, 1½ to 2½ mm. long. Leaves with distinct lateral nerves .. .. 1. *P. aviculare.*

3. Stems twining or prostrate. Leaves triangular-ovate with acuminate apex and sagittate base. Fruit about 3½ or 4 mm. long, trigonous, dull black. Fruit-bearing perigone green, sharply trigonous or with 3 very narrow wings .. 15 *P. Convolvulus.*
   Stems not twining. Fruit at most 3 mm. long. Fruit-bearing perigone not sharply trigonous nor trialate .. .. 4.

4. Spikes short, globose or ovate, in dichotomous inflorescences .. .. .. 5.
   Spikes more oblong, cylindrical to filiform .. .. 6.

5. Internodes and petioles with few or without prickles, the other parts mostly without prickles and quite glabrous, Inflorescences usually seemingly lateral, opposite to a leaf. Ocreæ obliquely truncate, glabrous; ocreæ and bracts eciliate .. .. 12. *P. dichotomum.*
   Internodes, petioles, and thickest nerves below usually strongly prickled. Inflorescences terminal or seemingly lateral. Ocreæ horizontally truncate, with appressed hairs. Ocreæ and bracts ciliate .. .. 13. *P. strigosum.*

6. Plant often prickly. Leaves narrowly triangular with hastate or sagittate base .. .. 14. *P. prœtermissum.*
   Plant without prickles. Leaves neither hastate nor sagittate .. .. .. 7.

7. All or nearly all fruits trigonous .. .. 8.
   All or nearly all fruits lenticular .. .. 10.

8. Fruit-bearing perigone under the lens with many glandular dots. Taste of leaves and perigones burning. Fruit dull because of minute wrinkles .. .. 11. *P. Hydropiper.*
   Fruit-bearing perigone without glands. Taste of leaves and perigones not burning. Fruit shining .. .. 9.

9. Perennial herb. Stems robust, the lower part creeping in the mud, the rest erect. Leaves lanceolate, often more than 12 cm. long. Ocreæ ciliate, the cilia 1 to 2 cm. long. Spikes cylindrical, dense, greenish white .. .. 3. *P. barbatum.*
   Annual or perennial. Stems more delicate, often prostrate. Leaves lanceolate or narrower, up to 8 cm. long, up to 1 cm. broad. Ocreæ ciliate, the cilia delicate, up to 1 cm. long. Spikes narrow, cylindrical to filiform, reddish or white .. 7. *P. minus.*

10. Fruit dull .. .. 11.
    Fruit shining .. .. 12.

11. Perigone not glandular. Spikes up to 4 cm., uninterrupted and leafless, solitary terminal and axillary. Ocreæ often provided with a spreading foliaceous green limb. Fruit about 1½ mm. long and nearly as broad, with suborbicular, very convex sides .. .. 8. *P. prostratum.*
    Perigone with many glandular dots. Spikes narrow, almost filiform, usually more than 5 cm. long, in the lower part with rudiments of leaves at the bracts. Ocreæ without spreading green limb. Fruit 2 to 3 mm. long, with subelliptical, less convex sides .. .. 11. *P. Hydropiper.*

12. Leaves ovate-cordate, long-petioled. Ocreæ at least partly with a green, spreading limb. Stout annual herb with many thick nutant spikes. Fruit 2 to 3 mm. long .. 6. *P. orientale.*
    Leaves linear-lanceolate to ovate-lanceolate. Ocreæ without spreading green limb .. .. 13.

13. Ocreæ and bracts entirely or nearly eciliate .. .. 14.
Ocreæ, at least when young, distinctly ciliate .. .. 15.

14. All parts glabrous or nearly so. Perigone without glands. Fruit about 2 mm. long and broad, often mucronate, not concave at both sides. Sheath of the leaf 1 to 2½ cm. long. .. .. 4. *P. glabrum.*
At least the petiole and the midrib beneath with appressed hairs; moreover often white or gray tomentum on the leaves and the stems. Perigone with viscous glands. Fruit slightly concave at both sides, shortly acuminate, but not mucronate. Sheath of the leaf less than 1 cm. long .. .. 10. *P. lapathifolium.*

15. Stout perennial herb. Stem mostly creeping in the mud and ramifying in the lower part, for the rest erect and only little branched. Spikes in racemes or panicles. Leaves often 15 to 20 cm. long. Sheath of the leaf 1 to 2½ cm. long .. 5. *P. attenuatum.*
Less stout plant. Stem often prostrate. Spikes solitary or in racemes. Leaves smaller, shortly petioled or almost sessile. Sheath of the leaves less than 1 cm. long .. .. 16.

16. Leaves ovate to lanceolate. Ocreæ with short and delicate cilia. Bracts eciliate or at most with the same glandular hairs on the margin as on the surface. Nearly the whole plant, the perigones excepted, densely glandular, especially the peduncles and the bracts. Fruit about 2 mm. long. Spikes cylindrical, dense .. .. 9. *P. elatius.*
Leaves lanceolate to linear. Ocreæ long-ciliated, bracts ciliate or not. Whole plant without glands. Fruit rarely longer than 1½ mm. Spikes slender .. .. .. 7. *P. minus.*

SECTION I.—AVICULARIA.

Mostly annual. Stems herbaceous or woody at the base. Leaves usually small, suborbicular to linear or spathulate, the petiole short, articulate at the base. Ocreæ membranous from youth, incised or lacerate in different ways. Flowers clustered in the axils of normal leaves or forming indistinct spikes towards the ends of the stems. Perigone usually 5-merous. Stamens 5 to 8, all of them or only those of the interior whorl dilatate. Fruit-bearing perigone herbaceous. Fruit nearly always 3-gonous.

Sectio *Avicularia* Meisn., Mon. gen. Pol. prodr., p. 43 et 85 (1826) (non vidi); in D.C., Prodr., XIV., p. 85 (1856); Benth. et Hook. F., Gen. pl., III., p. 97 (1883); Dans., Bull. Jard. Bot. Buit., sér. III., VIII., p. 140 (1927).

1. **Polygonum aviculare.**—Annual. Stems strongly branched, herbaceous, diffusely prostrate or ascending or rarely erect. Internodes very numerous, shorter or longer than the leaves. Leaves small, mostly 1 to 3 cm. long, elliptical to lanceolate or spathulate, with distinct lateral nerves. Ocreæ membranous, with more than 2 longitudinal nerves, irregularly incised. Flowers mostly 3 to 6 together in the axils. Fruit-bearing perigone 3-gonous, attenuate at the base or not. Fruit trigonous, dull because of minute longitudinal wrinkles, broadest in or below the middle, 1½ to 2½ mm. long.

P. aviculare Linn., Sp. pl., ed. 1, I., p. 362 (1753) ; Hook, F., Fl. Nov. Zel., I., p. 210 (1853) ; Meisn., in D. C., Prodr., XIV., p. 97 (1856) ; Benth., Fl. austr., V., p. 267 (1870) ; Bail., Syn. Queensl. Fl., p. 413 (1883) ; Hook. F., Fl. Br. Ind., V., p. 26 (1890) ; Bail., Queensl. Fl., IV., p. 1270 (1901).

General distribution.—Europe, extra-tropical Asia ; introduced elsewhere in many places.

Distribution in Queensland.—Tarampa Creek, Bailey ; Ipswich, 1909, Hall 287 ; Grandchester, 1910 ; Clifton, X. 1920, Quodling ; Charleville, XII. 1916, Bick ; Albert River (Southern Queensland), VIII. 1919, Brass 19.

P. aviculare is a very polymorphous species, originating from the cold and temperate regions of the northern hemisphere. On the southern hemisphere it is only adventive, but it is naturalised in many places, also in Australia. The delimitation between *P. aviculare* and its allies is still insufficiently examined. In Europe three distinct subspecies and many unimportant varieties have been described, but it seems premature to distinguish any of them among the few Australian plants I have happened to see. As to the relations with *P. plebeium* see this species.

2. **Polygonum plebeium.**—Annual. Stems strongly branched, herbaceous or woody at the base, diffusely prostrate. Internodes very numerous, usually shorter than the leaves. Leaves small, mostly less than 1 cm., rarely up to 2 cm. long, lanceolate to spathulate, with invisible lateral nerves. Ocreæ with 2 longitudinal nerves, irregularly incised. Flowers 1 to 5 in the axils of the leaves. Fruit-bearing perigone 3-gonous, carinate, shortly attenuate at the base. Fruit 3-gonous, shining, broadest near the middle, about 1 to 1½ mm. long.

P. plebeium R. Br., Prodr., p. 420 (1810) ; Benth., Fl. austr., V., p. 267 (1870) ; Bail., Syn. Queensl. Fl., p. 413 (1883) : Hook. F., Fl. Br. Ind., V., p. 27 (1890) ; Bail., Queensl. Fl., IV., p. 1270 (1901) ; Dans., Bull. Jard. Bot. Buit., sér. III., VIII., p. 140 (1927) ; *P. Dryandri* Hook. F., Fl. Nov. Zel., I., p. 210 (1853) ; *P. styligerum*, *P. anomalum*, *P. Miquelianum*, *P. effusum*, *P. Roxburghii*, *P. plebeium*, *P. herniariodes*, *P. illecebroides*, *P. cliffortioides*, *P. Perrottetii*, *P. ciliosum* Meisn., in D. C., Prodr., XIV., p. 91–95 (1856).

General distribution.—South Africa, tropical Africa, Egypt, tropical Asia to China, Formosa, and the Philippines, Java, Australia.

Distribution in Queensland.—Herbert River, Eaton ; Georgina River, IX., 1910, Bick 99 ; Proserpine, Michael 829 ; bed of Proserpine River, Michael 685 ; Pioneer River, Bailey ; Nebo (Northern Queensland), Gulliver (H. M.) ; Rockhampton, Dietrich 636 (H. B.) ; between Emerald and Longreach, 1913, Jarvis ; Tarampa Creek, Bailey ; Wyaga (Goondiwindi district), IX., 1919, White ; Eulo, XII., 1896, Bailey.

P. plebeium is not less polymorphous than its ally *P. aviculare*. This has caused the description of a large number of species, that have been united again by Hooker [12, p. 27] to a single species under the oldest name.

In this way we have, in my opinion, got nearer to the truth, if we consider the species as a syngameon. Elsewhere [9, p. 142] I even have suggested that *P. aviculare* and *P. plebeium* might be only races of a single syngameon. I was led to this idea by the remarkable fact that the areas of these two species only partly transgress each other. *P. aviculare* inhabits the extra-tropical regions of the northern hemisphere, *P. plebeium* is found in the tropical regions of the Old World and in the countries south of them. An exact examination in the boundary regions has not yet taken place. It would also be of great importance to know whether in those places in Australia, where it has been introduced, *P. aviculare* hybridises with *P. plebeium* and forms fertile progeny with it, or not. In the first case *P. plebeium* could not be maintained as a species apart from *P. aviculare*.

SECTION II.—PERSICARIA.

Perennial or annual. Stems herbaceous, rarely a little woody at the base. Leaves from ovate or cordate to lanceolate or linear, penninervous, without articulation at the base of the petiole. Ocreæ cylindrical at least when young, horizontally truncate, often ciliate. Flowers in the axils of bracts, crowded into spike-like racemes, the racemes mostly leafless, terminal or grouped into larger inflorescences, rarely foliate at the base or axillary. Perigone 4– to 6–merous, often coloured. Fruit-bearing perigone membranous to herbaceous. Fruit lenticular or trigonous.

Sectiones *Persicaria* (excl. § 2) et *Amblygonon* Meisn., Mon. gen. Pol. prodr., p. 66, 43 et 53 (1826) (non vidi) ; sectiones *Persicaria* et *Amblygonon* Meisn., in D. C., Prodr., XIV., p. 101 et 123 (1856) ; sectio *Persicaria* Benth. et Hook. F., Gen. pl., III., p. 98 (1883) ; Dans., Bull. Jard. Bot. Buit., sér. III., VIII., p. 143 (1927).

In the delimitation of the section *Persicaria* I follow Bentham and Hooker, who in their "Genera Plantarum" [5, p. 98] unite the sections *Persicaria* and *Amblygonon* of Meisner under the first name. Not only the difference in the embryo (which is accumbent in *Persicaria*, incumbent in *Amblygonon*) would be of too little importance to distinguish two sections, but moreover this difference is not a real one. In *P. orientale*, one of the two species, on which is based the section *Amblygonon*, the embryos are partly accumbent, partly incumbent. I have discussed this subject more in detail in my revision of the Polygonaceæ of the Netherlands East Indies [9, p. 143).

3. **Polygonum barbatum.**—Perennial herb. Stems stout, the lower part creeping in the mud, the rest erect. Inflorescences terminal or lateral afterwards because of the development of an axillary branch. Internodes cylindrical, glabrous or more or less covered with rather thick appressed hairs. Leaves nearly sessile, 1 to 2 dm. long, lanceolate, broadest near the middle, glabrous or more or less covered with appressed hairs, seldom silky, always more densely haired below than above. Sheath short. Ocreæ cylindrical, glabrous or more or less densely appressedly haired, with ciliate margin, the cilia 1 to 2, rarely up to 3 cm. long. Spikes in racemes or panicles,

densely cylindrical. Bracts narrowly infundibulate, with long cilia. Fruit-bearing perigone glabrous, without glands. Fruit 3-gonous, shortly acuminate, about 2 mm. long, brownish black, shining.

P. barbatum Linn., Sp. pl., ed. 1, I., p. 362 (1753) ; Benth., Fl. austr., V., p. 270 (1870) ; Bail., Syn. Queensl. Fl., p. 414 (1883) ; Queensl. Fl., IV., p. 1272 (1901) ; Dans., Bull. Jard. Bot. Buit., sér. III., VIII., p. 145 (1927) ; *P. stagninum*, *P. barbatum* et *P. fissum* Meisn., in D. C., Prodr., XIV., p. 104 et 105 (1856) ; *P. barbatum* et *P. serrulatum* Hook. F., Fl. Br. Ind., V., p. 37 et 38 (1890).

General distribution.—South Africa, tropical Asia to China, Formosa, and the Philippines, Malay Peninsula, Malay Archipelago, Queensland.

Distribution in Queensland.—Proserpine, Michael 1008 ; Hamilton Plain near Proserpine, Michael 1164 ; Mount Perry, Keys 718 et 735 ; Bellenden-Ker Range, VIII. 1881, Karster (H. M.).

P. barbatum is a tropical plant, the area of which extends to tropical Australia. As the African *Polygona* have not yet been critically revised, I am not sure that the specimens, mentioned under this name, really belong to this species. The single plant I saw under this name certainly belonged to another species.

4. **Polygonum glabrum.**—Perennial herb. Stems creeping in the mud and branched at the base, erect for the greater part, up to 1 m. high and higher, but little branched, stout and slender, often more than 1 cm. thick at the base. Internodes cylindrical, glabrous. Leaves 15 to 20 cm. long, lanceolate, broadest a little below the middle, long-acuminate, attenuate at the base, glabrous on both sides, often glandular beneath. Petiole 1 to 3 cm. long. Sheath 1 to 2½ cm. long. Ocreæ long and narrowly cylindrical, glabrous, eciliate. Spikes in racemes or panicles, long, dense, and cylindrical. Bracts infundibulate, very obliquely truncate. Fruit-bearing perigone compressed, glabrous, and without glands. Fruit lenticular, the sides about 2 mm. long and broad, one side convex, the other one usually slightly concave, shortly acuminate or mucronulate, brownish black, shining.

P. glabrum Willd. Sp. pl., II., 1, p. 447 (1799) ; Meisn., in D. C., Prodr., XIV., p. 114 (1856) ; Hook. F., Fl. Br. Ind., V., p. 34 (1890).

General Distribution.—Tropical parts of Asia, Africa, America, and Australia.

Distribution in Queensland.—Aramac, III. 1918, White.

P. glabrum is remarkable for the almost total absence of cilia and hairs. For the rest, however, it is very difficult to distinguish it from the allied species, such as *P. attenuatum*, *P. celebicum*, and *P. javanum* [9, p. 159–168]. The scattered occurrence in the tropical parts of different continents suggests that *P. glabrum* perhaps may be only the sum of glabrous varieties of other species. In Queensland, too, it requires examination, if glabrous forms of *P. attenuatum* exist and if it is possible to distinguish them from *P. glabrum*. The above-mentioned specimen from Aramac agrees exactly with the plants I have seen from the Asiatic continent.

5. **Polygonum attenuatum.**—Perennial herb. Stems creeping (in the mud) in the basal part, for the rest erect, stout and slender, up to 1 m. and higher, at the base often more than 1 cm. thick. Internodes cylindrical, glabrous. Leaves usually 15 to 20 cm. long, lanceolate, broadest at one-third of the length, long-acuminate, attenuate at the base, more or less densely hairy on both sides, often silky, moreover with more or less numerous glands. Petiole 1 to 3 cm. long. Sheath 1 to 2½ cm. long. Ocreæ long and narrowly cylindrical, rather densely covered with fine appressed hairs (the hairs exserted above the margin and imitating cilia), moreover in youth shortly and finely, afterwards indistinctly ciliate. Spikes in racemes and panicles, long and densely cylindrical, overhanging. Bracts infundibulate, very obliquely truncate, with appressed hairs especially near the margin, with short but distinct marginal cilia. Fruit-bearing perigone compressed, glabrous and without glands. Fruit lenticular, about 2 mm. long and broad, flat or slightly convex on one side, flat or slightly concave on the other side, mostly with a ½ to ¾ mm. long mucro, brownish black, shining.

P. attenuatum et *P. articulatum* R. Br., Prodr., p. 420 (1810) ; Meisn., in D. C., Prodr., XIV., p. 117 (1856) ; Benth., Fl. austr., V., p. 272 et 270 (1870) ; Bail., Syn. Queensl. Fl., p. 415 et 414 (1883) ; Queensl. Fl., IV., p. 1270 et 1272 (1901) ; non *P. articulatum* Linn., Sp. pl., ed. 1, I., p. 363 (1753) ; *P. attenuatum* et *P. australe* Spreng., Syst., II., p. 257 et 258 (1825) ; *P. attenuatum* Dans., Bull. Jard. Bot. Buit., sér. III., VIII., p. 162, ic. 5 (1927).

General Distribution.—Australia, Soemba (Netherlands East Indies).

Distribution in Queensland.—Gilbert River, II. 1922, White 1429 ; Proserpine, Michael 831 ; Sandgate Lagoon, 1909, White ; *ibidem*, VI., 1915, White ; Enoggera Reservoir, Bailey ; *ibidem*, V. 1911, White ; *ibidem*, VI. 1919, White.

Under the above-mentioned plants there are specimens which agree with the description of *P. attenuatum* as well as such which agree with that of *P. articulatum* as given by Brown and Bentham. Yet I cannot distinguish these two forms as separate species, even not as subspecies or varieties. I am therefore convinced that, like in other species, Brown has described two different forms of one species under different binomina. As in 1810, there existed already a *P. articulatum* of Linne, the homonym of Brown is a so-called dead-born name, and thus for the present species only *P. attenuatum* can be the valid specific name.

6. **Polygonum orientale.**—Annual herb. Stem erect or with a prostrate base, strongly and spreadingly branched, in the basal part up to 1½ cm. thick or even thicker. Internodes cylindrical, swollen at the nodes, rather long and spreadingly hairy, more or less glandular in the upper part of the stems. Lamina 5 to 15 cm. long, ovate-cordate, acuminate, rounded or cordate at the base, rather densely hairy above, on the nerves with spreading, between the nerves with appressed hairs, beneath hairy in the same way, only more densely and moreover with numerous sessile glands. Petiole

about two-thirds of the lamina in length, densely and spreadingly hairy. Sheath short. Ocreæ short-cylindrical, the tube 1½ times to twice as long as it is broad, at the top spreading into a green limb with appressed hairs and 2 to 3 mm. long cilia. Spikes all or for the greater part in the axils of small leaves, grouped into a spreadingly branched, leafly panicle in large plants, dense and cylindrical. Bracts infundibulate, very obliquely truncate, swollen by the numerous pedicels, densely covered with appressed hairs, moreover glandular and ciliate. Fruit-bearing perigone compressed, glabrous, without glands. Fruits lenticular or trigonous for a very small part, the lenticular ones on one side flat or slightly concave with a slight thickening in the middle, on the other side flat or very slightly canaliculate, shortly acuminate at the top but with mucro, almost 3 mm. long, a little broader than they are long, brownish black, shining.

P. orientale Linn., Sp. pl., ed. 1, I., p. 362 (1753) ; R. Br., Prodr., p. 420 (1810) ; Meisn., in D. C., Prodr., XIV., p. 123 (1856) ; Benth., Fl. austr., V., p. 271 (1870) ; Bail., Syn. Queensl. Fl., p. 414 (1883) ; Hook. F., Fl. Br. Ind., V., p. 30 (1890) ; Bail., Queensl. Fl., IV., p. 1270 (1901) ; Dans., Bull. Jard. Bot. Buit., sér. III., VIII., p. 168 (1927).

General Distribution.—Tropical Asia from Turkestan to China, Japan, Corea, the Malay Archipelago, Australia.

Distribution in Queensland.—Johnstone River, X. 1917, Ladbrook 136 ; Rockingham Bay, Dallachy (H. M.) ; Mt. Julian, near Proserpine, Michael 882 ; Gordon Downs, Weld Blundell 16 ; Bundaberg, IV. 1911, Johnston ; Fraser Island, XII. 1919, Epps 172 ; Noosa Heads, I. 1920, White ; Gootchie Creek, Gundiah, II. 1923, Kajewski (H. B.) ; Northgate-Nudgee, 13 IV. 1907, White ; Ekibin, in creeks, 8 V. 1909, White ; Enoggera Creek, Bailey ; Goodna, III. 1913, White ; Wellington Point, 17 III. 1916, White ; Mudgeeraba, VI. 1914, White ; Wallumbilla, V. 1916, White ; Albert River (Southern Queensland), V. 1919, Brass 2 ; Killarney (Southern Queensland), Wedd.

7. **Polygonum minus.**—Annual or perennial herb. Stems rather slender, prostrate or ascending, branched especially in the lower part. Internodes cylindrical, glabrous or with appressed hairs. Leaves almost sessile, lanceolate to linear, obtuse or acute, mostly rounded at the base, hairy in different degrees, at least hairy on the nerves below. Sheaths short. Ocreæ narrowly cylindrical, more or less hairy with appressed bristles, the marginal cilia 1 cm. or longer. Spikes 1 to 3 at the ends of the stems, narrowly cylindrical to filiform, mostly interrupted in their lower part. Bracts infundibulate, obliquely truncate, glabrous, mostly ciliate. Fruit-bearing perigone glabrous and without glands. Fruit lenticular or trigonous, very shortly acuminate, very shining, black, 1 to 2 mm. long, the lenticular ones with ovate, convex sides.

P. minus Huds., Fl. Angl., ed. 1, p. 148 (1762) (non vidi) ; Hook. F., Fl. Br. Ind., V., p. 36 (1890) ; Dans., Bull. Jard. Bot. Buit., sér. III., VIII., p. 174, ic. 8, 9 10 (1927) ; *P. subsessile* et *P. decipiens* R. Br., Prodr., p. 419 et 420 (1810) ; *P. decipiens*, *P. serrulatum* pro parte, *P. minus* et *P. subsessile*

Meisn., in D. C., Prodr., XIV., p. 104, 110, 111, 113 (1856); *P. minus* et *P. subsessile* Hook. F., Fl. Tasm., I., p. 306 (1860); Benth., Fl. austr., V., p. 269 (1870); Bail., Syn. Queensl. Fl., p. 414 (1883); Queensl. Fl., IV., p. 1271 (1901).

General Distribution of the Species.—Europe, temperate and tropical Asia, Philippines, Malay Archipelago, Australia.

Ssp. *subsessile*.—Slender, but often stouter than the ssp. decipiens. Internodes, ocreæ, leaves and peduncles mostly densely covered with long, rigid, spreading hairs, especially the ocreæ and the leaves below. Bracts either ciliate or not. Fruits lenticular, about 2 mm. long, with very convex sides.

P. subsessile R. Br., Prodr., p. 419 (1810); Meisn., in D. C. Prodr., XIV., p. 113 (1856); Hook. F., Fl. Tasm., I., p. 306 (1860); Benth., Fl. austr., V., p. 269 (1870); Bail., Syn. Queensl. Fl., p. 414 (1883); Queensl. Fl., IV., p. 1271 (1901); *P. minus* ssp. *subsessile* Dans., Bull. Jard. Bot. Buit., sér. III., VIII., p. 176 (1927).

General Distribution of the ssp. *subsessile*.—Australia, Tasmania, New Guinea.

Distribution in Queensland.—Cairns, I., 1918, White; Yarrabah, VII., 1918, Michael 460; Cabbage Tree Creek, V., 1898, Bailey; Kedron Brook, near Brisbane, VI., 1875, Bailey; Kulara, Bick; Maroochy, Bailey; Kin Kin, III., 1916, White and Francis.

Ssp. *decipiens*. Slender. Internodes glabrous. Ocreæ with scattered appressed hairs. Leaves with short, appressed bristles, at least on the nerves below, often on the whole lower surface, rarely on the upper surface with appressed hairs. Ocreæ ciliate. Fruits for the greater part or all of them triquetrous, about 1½ mm. long.

P. decipiens, R. Br., Prodr., p. 420 (1810); Meisn., in D. C., Prodr., XIV., p. 105 (1856); *P. minus* Hook. F., Fl. Tasm., I., p. 306 (1860); Benth., Fl. austr., V., p. 269 (1870) saltem pro parte; Bailey, Syn. Queensl. Fl., p. 414 (1883); Queensl. Fl., IV., p. 1271 (1901); *P. minus* ssp. *decipiens* Dans., Bull. Jard. Bot. Buit., sér III., VIII., p. 178 (1927).

General Distribution of the ssp. *decipiens*.—Not exactly known (Australia, Tasmania).

Distribution in Queensland.—Proserpine, Michael 1384 (H. B.); Rockhampton, III., 1907, Cleminson; Eumundi, IV., 1911, White; between Woombye and Buderim Mountain, V., 1911, White; Moreton Bay, McGillavray (H. M.); Sandgate Lagoon, 1909; Bunya Mountains, X., 1919, White; Laidley, III., 1921, White; Ipswich, 1908, Hall 106; Enoggera Reservoir, Bailey; Enoggera, 17, III., 1914, White; Wellington Point, 17, III., 1916, White; Nerang, XII., 1913, White; Blackall Range, XI., 1916, White.

P. minus, ssp. not recognisable.—Mount Perry, Keys; Mulgrave River (North Queensland), Bailey; Rockhampton, O'Shanesy (H. M.); Malanda, I., 1918, White.

Under the name *P. minus* I join together the plants described by Brown as two different species, viz., *P. subsessile* and *P. decipiens*. These two Polygona are easily distinguishable, intermediate forms have not been denoted with certainty, and, if I had seen no other specimens than the above I would undoubtedly maintain them as well-defined species. While revising the Polygona of the Netherlands East Indies [9, p. 174–183], however, I have not been able to separate the ssp. *micranthum*, *depressum*, and *procerum*, as distinct species. The difference between typical specimens of these sub-species is pretty large, but the differences between the extremes are very small, and it was not always possible to decide whether there were real or only seeming intermediate forms. Moreover several specimens from New Guinea apparently approach the Australian sub-species. It is for this reason that, in agreement with my revision of the Polygonaceæ of the Netherlands East Indies, I prefer to consider *P. subsessile* and *P. decipiens* too, as sub-species of *P. minus*. It is certainly incorrect to keep apart *P. subsessile* as a distinct species and unite *P. decipiens* at the same time with the European *P. minus*, as Hooker and Bentham do. By its hairiness, on first sight *P. subsessile* differs much more from the European *P. minus* than does *P. decipiens*, but when examined more carefully it appears to be very similar to the ssp. *procerum* from the northern and eastern part of the Malay Archipelago. If one prefers to accept smaller species, both Australian sub-species should get the binomina ; under which Brown originally described them.

Brown describes the bracts of *P. decipiens* as "nudæ," *i.e.*, without cilia, and the fruits as trigonous. All the above-mentioned specimens of the ssp. *decipiens* have (with exception of a few without fruits) trigonous nuts, but ciliate bracts. I found eciliate bracts only in one plant from New Zealand, but this specimen possessed lenticular fruits. Hooker also saw plants with trigonous nuts and eciliate bracts [11, p. 306]. A further examination of the Australian plants of the *minus* group is still wanted.

8. **Polygonum prostratum.**—Herbaceous. Stems diffusely branched. Internodes cylindrical, mostly with rather long spreading hairs, rarely glabrous. Leaves ovate-lanceolate to ovate-linear, subobtuse at the top, rounded or attenuate at the base, mostly on both sides but especially on the nerves below with long, somewhat spreading hairs, rarely quite glabrous. Petiole and sheath very short. Ocreæ with scattered appressed hairs or glabrous, eciliate, often with a spreading, leafy, deeply toothed or palmatifid, scantily ciliate limb. Spikes solitary at the end of the stem and its branches and in the axils of the leaves, cylindrical, interrupted at the base. Bracts infundibulate, obliquely truncate, eciliate. Fruiting perigone glabrous and without glands. Fruit lenticular with very convex sides, nearly always dull, very rarely shining, 1 to 1½ mm. long.

P. prostratum R. Br., Prodr., p. 419 (1810) ; Hook. F., Fl. Nov. Zel., I., p. 209 (1853) ; Meisn., in D. C., Prodr., XIV., p. 116 (1856) ; Hook. F., Fl. Tasm., I., p. 307 (1860) ; Benth., Fl. austr., V., p. 268 (1870) ; Bail., Syn. Queensl. Fl., p. 413 (1883) ; Queensl. Fl., IV., p. 1271 (1901).

General Distribution.—Australia, Tasmania, New Zealand.

Distribution in Queensland.—Roma, IV., 1909, White; Nanango, III., 1918, Grove; Laidley, III., 1921, White; Brisbane, Ipswich Road, III., 1916, Bick; Tarampa, Bailey; Hendon, XII., 1912, White; Taabinga VI., 1912, White.

P. prostratum occurs only in Australia and the surrounding islands, and appears to be sharply distinguished from all other species I know. Some striking but unimportant varieties exist, one with shining fruits, only seen by me from Western Australia, and an entirely glabrous one, already mentioned by Brown.

9. **Polygonum elatius.**—Herbaceous, probably annual. Stems strongly, almost dichotomously branched. Internodes cylindrical, slender, densely covered with short glandular hairs and sessile glands, for the rest glabrous. Leaves ovate-lanceolate, acuminate towards the subobtuse apex, suddenly contracted at the base, under the contraction gradually attenuate into the petiole, densely covered with sessile glands, especially below, glabrous for the rest, minutely serrulate at the margin because of short bristles. Petiole about 1 cm. long, glandular as is the stem. Ocreæ cylindrical when young, slightly infundibuliform at the top, densely covered with short glandular hairs and sessile glands, ciliate at the margin, the cilia up to 3 mm. long, for the rest without hairs, afterwards mostly lacerate. Spikes almost in racemes at the ends of the stems when young, afterwards 2 to 5 together on an almost dichotomous peduncle, each spike pedunculate, cylindrical, often interrupted at the base. Bracts imbricate, infundibulate, obliquely truncate, densely covered with short glandular hairs and sessile glands, eciliate. Fruit-bearing perigone compressed, ovate, glabrous and eglandular. Fruit lenticular, flat on one side, on the other side convex, especially towards the base, black, shining, ovate or orbicular, slightly acuminate.

P. elatius R. Br., Prodr., p. 419 (1810); Meisn., in D. C. Prodr., XIV., p. 121 (1856).

General Distribution.—Unknown. Only recorded by Brown from Port Jackson in New South Wales.

Distribution in Queensland.—Brisbane, 10, XI., 1888, Simmonds; Ekibin Creek, near Brisbane, I., 1916, White.

I cannot identify the above-mentioned plants from Brisbane with any other species. They perfectly agree with the original description of Brown's *P. elatius*. I am therefore obliged to suppose that Bentham was wrong in uniting this species with *P. lapathifolium* [4, p. 271]. *P. elatius* seems to be closely allied with *P. Persicaria*, though the differences are so important that it cannot be considered as a form of this species. *P. elatius* having been confounded with *P. lapathifolium* up to the present, its distribution is almost unknown. Brown mentions it from Port Jackson, and this well agrees with the fact that it now proves to occur near Brisbane.

10. **Polygonum lapathifolium.**—Annual (or rarely perennial ?) herb. Stem mostly slender, erect, ascending or rarely prostrate. Internodes slender, below thicker than above, often swollen at the nodes, glabrous or

Polygonum elatius R.Br. *a*, Flowering and fruiting branch, natural size *b*, Fragment of a flowering spike, × 5 ; *c*, Fruit-bearing perigone, × 10; *d*, Fruit, × 10.

more or less tomentose. Leaves mostly ovate-lanceolate, broadest mostly below the middle, acuminate, acute or subobtuse, attenuate at the base, above towards the margin with short appressed hairs, below on the thickest nerves with appressed short hairs and glandular dotted over the whole surface, sometimes moreover with a grey or white tomentum above and below or only below. Petiole and sheath short. Ocreæ at first cylindrical, afterwards mostly lacerated, eciliate or almost eciliate, glabrous or with few appressed hairs or seldom covered with a grey or white tomentum. Peduncles glabrous or glandular or tomentose. Spikes solitary or grouped at the ends of the stems into racemes or panicles. Bracts ovate amplexicaul, obtuse, acute or acuminate, eciliate or nearly so. Fruit-bearing perigone more or less glandular dotted. Fruits nearly all lenticular, with ovate to orbicular, slightly concave sides, shortly acuminate, brown or black, shining or dull.

P. lapathifolium Linn., sp. pl., ed. 1, I., p. 360 (1753) ; Dans., Rec. trav. bot. néerl., XVIII., p. 125, t. I.–III. (1921) ; Bull. Jard. Bot. Buit., sér. III., VIII., p. 185 (1927) ; *P. lanigerum* et *P. glandulosum* R. Br., prodr., p. 419 (1810) ; *P. glandulosum. P. lanigerum, P. nodosum, P. lapathifolium, P. glutinosum* Meisn., in D. C., prodr., XIV., p. 116-120 (1856) ; *P. lapathifolium* et *P. lanigerum* Benth., Fl. austr., V., p. 270 et 271 (1870) ; Bail., Syn. Queensl. Fl., p. 414 (1883) ; Hook. F., Fl. Br. Ind., V., p. 35 (1890) ; Bail., Queensl. Fl., IV., p. 1272 et 1273 (1901).

General Distribution.—Europe, Africa, Asia, Australia ; in America introduced at many points and quite naturalised.

Distribution in Queensland.—Georgina River, IX., 1910, Bick ; Gordon Downs, Weld Blundell 17 ; Wallumbilla, V., 1916, White ; Laidley, III., 1921, White ; Ipswich Road, near Brisbane, V., 1916, Bick ; Nanango, III., 1918, Grove ; Waterworks Road, Enoggera, near Brisbane, III., 1911, White ; Enoggera, on damp land, 18, III., 1912, White ; Enoggera Creek, Bailey ; creek at the base of Mount Cootha, Brisbane, XI., 1913, White ; Brisbane River, Bailey ; ibidem, 5, XII., 1908, White ; New Farm, Brisbane, Bailey ; Mudgeeraba Creek, XII., 1914, White ; Neerkol Creek, Bowman (H. M.) ; Nerang, XII., 1913, White ; Wyaga, Goondiwindi district, IX., 1919, White ; Blackall Range, XI., 1916, White ; Samford, III., 1910, White ; Darra, 11, XI., 1916, White.

Having made a special study of *P. lapathifolium* formerly [8], in the first place of the European forms, I wish to discuss it here somewhat more in detail. In Australia two capital forms may be distinguished, described by Brown as two distinct species under the names *P. glandulosum* and *P. lanigerum.* An exact study of these forms has pointed out that it is impossible to separate them from *P. lapathifolium* and from each other. Brown's *P. glandulosum* is the most slender form of *P. lapathifolium* with fine, strongly branched stems and the smallest perigones and fruits. It is the same form that Meisner described [16, p. 60] from Japan under the name *P. nodosum β Sakuratade*, a plant which also occurs in Southern Asia and Southern Africa. Indeed it very much resembles the European *P. lapathifolium* ssp. *nodosum* (= *P. nodosum* Pers.). The other Australian form is a plant I have seen from tropical Asia, Sumatra, Java, and Australia ; it is recorded moreover from South Africa. Its most striking feature is the grey or white tomentum, but as a rule all the parts of the plant, the fruits included, are larger. In some cases it resembles the European *P. lapathifolium* ssp *mesomorphum* Dans., or even the ssp. *tomentosum* Dans. (= *P. tomentosum* Schrank), in other cases it is only distinguishable from the other Australian form by its grey or white tomentum. The density and extent of the tomentum in *P. lapathifolium* is highly dependent on the outer circumstances and is consequently a distinctive character of little value. I therefore even refrain from distinguishing two sub-species.

It is worth mentioning, that of the Australian plants, which agree with Meisner's *P. nodosum* var. *Sakuratade*, the greater part has dull fruits, whilst similar plants from Asia and Africa have shining fruits. Dull fruits are also often found in the European *P. lapathifolium* ssp. *tomentosum*.

11. **Polygonum Hydropiper.**—Annual herb. Stem slender, mostly prostrate in the basal part, erect for the rest. Internodes cylindrical, below thicker than above, often swollen at the nodes, glabrous, often glandular. Leaves ovate-lanceolate to lanceolate-linear, broadest below the middle, acuminate, acute or subobtuse, attenuate at the base, almost glabrous above, mostly with appressed bristles on the nerves below. Petiole and sheath short. Ocreæ long-cylindrical, often lacerate or bottle-shaped because of the development of cleistogamous flowers in the axils of the leaves, with appressed bristles on the nerves, long-ciliate at the margin. Spikes very narrow, mostly filiform, interrupted and with rudiments of leaves on the bracts in the lower part, the rhachis glabrous or glandular. Bracts infundibulate, obliquely or horizontally truncate, ciliate, glabrous or glandular. Fruit-bearing perigone green for the greater part, coloured at the top, glandular dotted. Fruit lenticular or trigonous, dull because of minute wrinkles of the surface, brownish black, 2 to 3 mm. long, the lenticular ones nearly flat on one side, obtusely carinate on the other side.

P. Hydropiper Linn., Sp. pl., ed. 1, I., p. 361 (1753) ; Benth., Fl. austr., V., p. 269 (1870) ; Bail., Syn. Queensl. Fl., p. 413 (1883) ; Hook. F., Fl. Br. Ind., V., p. 39 (1890) ; Bail., Queensl. Fl., IV., p. 1271 (1901) ; Dans., Bull. Jard. Bot. Buit., sér. III., VIII., p. 187 (1927) ; *P. gracile* R. Br., Prodr., p. 419 (1810) ; *P. oryzetorum*, *P. flaccidum*, *P. Hydropiper* et *P. gracile* Meisn., in D. C., prodr., XIV., p. 106, 107, 109 (1856) ; non *P. flaccidum* Roxb., Fl. ind., II., p. 291 (1832), nec Hook. F., Fl. Br. Ind., V., p. 39 (1890).

General Distribution.—Europe, North Africa, Asia, Malay Archipelago, Australia.

Ssp. *microcarpum*.—Fruit about 2 mm. long. Whole plant more delicate and more glandulous. Thickest nerves of the leaves densely hairy below.

P. Hydropiper Hook. F., Fl. Br. Ind., V., p. 39 (1890) ; *P. oryzetorum*, *P. flaccidum*, *P. Hydropiper* pro parte et *P. gracile* Meisn., in D. C., Prodr., p. 106, 107 et 109 (1856) ; *P. Hydropiper* ssp. *microcarpum* Dans., Bull. Jard. Bot. Buit., sér. III., VIII., p. 189 (1927).

General Distribution of the ssp. *microcarpum*.—Tropical Asia, Malay Archipelago, tropical Australia.

Distribution of the ssp. *microcarpum* in Queensland.—Noosa Heads, I., 1920, White ; Nanango, III., 1918, Grove ; Eumundi, IV., 1911, White ; between Woombye and Buderim Mountain, V., 1911 ; Buderim Mountain, IV., 1916, White ; Enoggera, damp land, 18, III., 1912, White ; Enoggera, Waterworks Road, V., 1911, White ; Enoggera Creek, IV., 1908, White ; Simpson's Scrub, I., 1912, White ; Goodna, 18, III., 1907, White ; Ekibin Creek, I., 1916, White ; Ithaca Creek, I., 1916, White ; Three-Mile Scrub, near Brisbane, 1875, Bailey.

Ssp. *megalocarpum*.—Fruit about 3 mm. long. Whole plant coarser, less glandulous. Thickest nerves of the leaves less hairy or glabrous below.

P. Hydropiper Linn., Sp. pl., ed. 1, I., p. 361 (1753) ; Meisn., in D. C., Prodr., XIV., p. 109 pro parte (1856) ; *P. Hydropiper* ssp. *megalocarpum* Dans., Bull. Jard. Bot. Buit, sér. III., VIII., p. 188 (1927).

General Distribution of the ssp. *megalocarpum*.—Europe, temperate Asia, Southern Australia.

Distribution in Queensland.—Ekibin, near Brisbane, 8, V., 1909, White.

I have already discussed the synonymy of *P. Hydropiper* elsewhere [9, p. 191-192]. The distribution of the different forms is very curious. The ssp. *megalocarpum* occurs in Europe, extra-tropical Asia and extra-tropical Australia. In the interjacent regions one only comes across the ssp. *microcarpum*. On the Asiatic continent this subspecies has lenticular fruits ; this variety (var. *lenticulare*) is also found in the Philippines, the Malay Peninsula, and the northern part of Sumatra. South of this in the Malay Archipelago only the variety with triquetrous fruits (var. *triquetrum*) of the ssp. *microcarpum* occurs. It is therefore curious, that of the ssp. *microcarpum* in Queensland only the var. *lenticulare* has been found. South of Queensland the distribution of the two subspecies is not yet sufficiently known, but it is quite certain that the ssp. *megalocarpum* is more frequent there. A distribution of subspecies and varieties so symmetrical with regard to the equator is very striking.

SECTION III.—CEPHALOPHILON.

Annual or perennial. Stems herbaceous or partly wooded, often climbing. Leaves very different in form, often more or less triangular, often sagittate or hastate. Ocreæ cylindrical, horizontally or obliquely truncate. Spikes globose to ovate, rarely longer. Bracts 1- or few-flowered. Perigone mostly 5-merous. Stamens 8 to 5. Fruit-bearing perigone membranous, herbaceous or baccate. Fruit lenticular or triquetrous or rarely almost globose.

Sectiones *Echinocaulon* et *Cephalophilon* Meisn., in Wall., Pl. as. rar., III., p. 58 et 59 (1832) ; in D. C., Prodr., XIV., p. 131 et 127 (1856) ; sectio *Cephalophilon* Benth. et Hook. F., Gen. pl., III., p. 98 (1883) ; Dans., Bull. Jard. Bot. Buit., sér. III., VIII., p. 200 (1927).

I follow Bentham and Hooker [5, p. 98] in uniting the sections *Cephalophilon* and *Echinocaulon* of Meisner under the name first mentioned. Indeed the differences between these two sections of Meisner are smaller than those between such and other sections of the genus *Polygonum.*

12. **Polygonum dichotomum.**—Herbaceous stems thin and weak, ascending or more or less climbing, often rooting in the lower part. Internodes long and thin, glabrous or with a whorl of rigid, retrorse, appressed bristles at the top. Leaves ovate-triangular to lanceolate, acute or slightly acuminate at the top, cuneate, rounded or truncate at the base, rarely hastate, glabrous or with short bristles at the margin, sometimes with retrorse bristles on the midrib below. Petiole short to rather long. Sheath very short, glabrous. Ocreæ long-cylindrical, membranous, obliquely truncate, on the side facing the leaf much shorter than on the opposite side, glabrous, eciliate. Inflorescences at first terminal, soon lateral because of the development of a branch in the axil of the uppermost leaf, once or twice dichotomously branched, bearing 2 to 4 spikes. Spikes ovate to short-cylindrical. Bracts elliptical to oblong, acute or acuminate, broadly sessile, glabrous, eciliate, 1- or 2-flowered. Fruit-bearing perigone glabrous. Fruit lenticular, with almost orbicular, very convex sides and sharp edges, shortly acuminate, $2\frac{1}{2}$ to 3 mm. long, $2\frac{1}{2}$ mm. broad, rather shining, yellowish brown.

P. dichotomum, P. tetragonum et *P. hispidulum* Bl., Bijdr., 11, p. 529 et 535 (1825) ; *P. pedunculare* Meisn., in Wall., Pl. as. rar., III., p. 58 (1832) ; Hook. F., Fl. Br. Ind., V., p. 48 (1890) ; *P. hispidulum, P. tetragonum* et *P. pedunculare* Meisn., in D. C., Prodr., XIV., p. 133 (1856) ; *P. dichotomum* Dans., Bull. Jard. Bot. Buit,. sér. III., VIII., p. 222 (1927).

General Distribution.—Tropical Asia from British India to China, Formosa, and the Philippines, the whole Malay Archipelago, Queensland, South Africa.

Distribution in Queensland.—Johnstone River, XI., 1917, Ladbrook 149 ; Proserpine, Michael 831 (H. B.) ; Proserpine River, Michael 851 ; Proserpine, along watercourses, Michael 851 (H. B.).

P. dichotomum is nearly always mentioned under the name of *P. pedunculare.* Since the authentic specimens have taught us that at least the *P. dichotomum* and the *P. tetragonum,* probably also the *P. hispidulum* of Blume, are synonyms of *P. pedunculare* Meisn., we are obliged to use one of Blume's names. In my revision of the Polygonaceæ of the Netherlands East Indies [9, p. 223] I have chosen the name *P. dichotomum* for this species as the valid one.

Though I have seen many specimens of this species from very different parts of its area, I have found no reason to unite it with *P. strigosum.* Both species are polymorph, but I could always distinguish them.

13. **Polygonum strigosum.**—Herbaceous. Stems long and weak, ascending or more or less climbing. Internodes long and thin, angulate, with retrorse prickles upon and between the edges, especially in the upper part. Leaves oblong to lanceloate, acute or acuminate, sagittate or hastate

at the base, with appressed rigid hairs above, rarely glabrous, with retrorse prickles on the midrib below, with short prickles on the margins, which are mostly directed towards the base in the basal part. Petiole up to 1 cm. long, with retrorse prickles. Sheath very short, with retrorse prickles. Ocreæ long-cylindrical, $1\frac{1}{2}$ to $2\frac{1}{2}$ cm. long, ciliate at the margin, with rigid appressed hairs, directed towards the top in the upper part, towards the base in the lower part. Inflorescences terminal or seemingly lateral because of the development of a branch in the axil of the uppermost leaf, 2 to 3 times dichotomously branched, bearing 3 to 5 spikes, the peduncles with glandular hairs towards the top. Spikes short, mostly ovate. Bracts ovate, obtuse acute or acuminate, broadly sessile, glabrous or with stellate hairs, ciliate at the margin, mostly 1-flowered. Fruit-bearing perigone glabrous. Fruit lenticular or triquetrous, dark brown, rather shining, about $2\frac{1}{2}$ mm. long.

P. strigosum R. Br. Prodr. p. 420 (1810); Benth. Fl. austr., V., p. 268 (1870); Bail., Syn. Queensl. Fl., p. 413 (1883); Hook. F., Fl. Br. Ind., V., p. 47 (1890); Bail., Queensl. Fl., IV., p. 1273 (1901); Dans., Bull. Jard. Bot. Buit., sér. III., VIII., p. 227, ic. 15 (1927), *P. horridum* Roxb., Fl. ind., II., p. 291 (1832); Meisn., in Wall., Pl. as. rar., III., p. 58 (1832); *P. horridum* et *P. strigosum* Meisn., in D. C., Prodr., XIV., p. 133 et 134 (1856).

General Distribution.—Tropical Asia from British India to China, Malay Archipelago, Australia.

Distribution in Queensland.—Rockingham Bay, Dallachy (H. M.); Eumundi, IV., 1911, White; Noosa Heads, I., 1920, White; Martin Creek, Buderim Mountain, Easter 1912, White; Northgate–Nudgee, 13, IV., 1907; Ekibin, 8, V., 1909, White; Enoggera Dam, Bailey; ibidem V., 1911, White; Maroochy, X., 1874, Bailey; Malanda, I., 1918, White.

14. **Polygonum prætermissum.**—Herbaceous. Stems 1 to 2 dm. long, diffusely prostrate, or longer, ascending or more or less climbing. Internodes angular, often with recurved prickles on the edges, especially in the upper part. Leaves lanceolate, obtuse or acute, hastate with obtuse lobes, glabrous or with scattered appressed hairs above, often with retrorse bristles on the thickest nerves below, serrulate because of very short marginal bristles. Petiole short, with or without retrorse prickles. Ocreæ cylindrical, horizontally truncate, sometimes with retrorse prickles at the base, glabrous and eciliate. Inflorescence terminal in the beginning, afterwards lateral because of the development of a branch in the axil of the uppermost leaf, once or twice dichotomously branched, terminating into 1 to 4 filiform interrupted spikes, often with spreading glandular hairs towards the spikes. Bracts all remote, ovate, obtuse, glabrous, not or sparingly ciliate. Fruit-bearing perigone glabrous. Fruit triquetrous, with convex sides, brown, shining, about $2\frac{1}{2}$ mm. long.

P. strigosum Hook. F., Fl. Tasm., I., p. 307 (1860); non R. Br.; *P. prœtermissum* Hook. F., Fl. Br. Ind., V., p. 47 (1890).

General Distribution.—British India, Philippines, Queensland, Victoria (in Herb. Bog.), Tasmania.

Distribution in Queensland.—Eight-Mile Plains, near Brisbane, 19, X., 1918, White.

The specimens of *P. prætermissum* from Brisbane do not agree in all parts with Hooker's original description and with the specimens I saw from British India. They are not "small, 6-8 inch," but much longer, the stems are not "nearly or quite unarmed" but distinctly prickled as in *P. strigosum*, the leaves have not much shorter petioles than in this species. Since, however, the other characters agree very well, I do not doubt whether the plants from Brisbane belong really to *P. prætermissum*. The specimens I saw from the Philippines were intermediate between those from British India and those from Queensland. In the Buitenzorg Herbarium there are also plants of this species from Victoria (Healesville, XI., 1906, Audas), which conform with those from Brisbane. I did not see specimens from Tasmania.

SECTION IV.—TINIARIA.

Herbs or undershrubs. Stems mostly dextrorsely twining, rarely erect. Leaves ovate to cordate or sagittate. Ocreæ often small or nearly absent. Flowers in loose axillary simple or branched racemes, which are often grouped into panicles. Perigone 5-merous, the three outer sepals larger than the two inner ones. Fruit-bearing perigone membranous or herbaceous, carinate or more or less winged. Fruit triquetrous.

Sectio *Tiniaria* Meisn., Mon. gen. Pol. prodr., p. 43 et 62, excl. § 2 (1826) (non vidi); emend. Meisn., in Wall., Pl. as. rar., III., p. 62; in D. C., Prodr., XIV., p. 135 (1856); Dans., Bull. Jard. Bot. Buit., sér. III., VIII., p. 236 (1927); sectiones *Tiniaria* et *Pleuropterus* Benth. et Hook. F., Gen. Pl., III., p. 99 (1883).

15. **Polygonum Convolvulus.**—Annual herb. Stems long and slender, dextrorsely twining, glabrous or with short papillous hairs. Leaves ovate-triangular, with sagittate base and acuminate apex, glabrous or with papillous hairs on the nerves below. Petiole about two-thirds of the lamina in length. Ocreæ short, eciliate. Flowers in clusters in the axils of normal leaves or in loose axillary spikes. Bracts remote, short, membranous, infundibulate, obliquely truncate, eciliate. Fruit-bearing perigone green, about as long as the fruit, 3-gonous, obtusely carinate or very narrowly winged. Fruit 3-gonous, black, dull, $3\frac{1}{2}$ to 4 mm. long.

P. Convolvulus Linn., Sp. pl., ed. 1, I., p. 364 (1753); Meisn., in D. C., Prodr., XIV., p. 135 (1856); Hook. F., Fl. Br. Ind., V., p. 53 (1890); Bail., Queensl. Agr. Journ., VII., p. 441, t. LX. (1900); Queensl. Fl., IV., p. 1273 (1901).

General Distribution.—Europe, Northern and Western Asia, North Africa, introduced elsewhere.

Distribution in Queensland.—Boney Mountain, X., 1917, Gibson; Brisbane Botanic Gardens, "came up in street sweepings," XI., 1918, White.

P. Convolvulus does not originally occur in Australia, but has been introduced from the temperate regions of the northern hemisphere; according to Bailey [2, p. 441] it is already naturalised in the environs of Brisbane.

POSTSCRIPT.

This publication had already gone to press when the following paper came to my knowledge:—K. Domin, Beiträge zur Flora und Pflanzengeographie Australiens (1921) (Bibliotheca botanica, 89, 1). In this publication Domin mentions some Polygonums that partly seemingly partly really form an amplification to the list of species given by me for Queensland and which I therefore will discuss briefly.

P. aviculare L. var. *diffusum Meisn.* (l. c., p. 611).—As the varieties of this species mentioned by Meisner and others do not show a natural subdivision, I would renounce distinguishing them, though it might be possible to find plants agreeing with the descriptions.

P. orientale L. var. *cochinchinense* Domin (l. c., p. 612). It is not clear why Domin gives this new name and does not use the older one mentioned by him among the synonyms, viz., *P. orientale* var. *pilosum* Meisn. Distinguishing varieties, founded on the different grades of hairiness, I would consider almost useless.

P. Hydropiper L. var. *vulgare* Dom. and var. *ciliare* Dom. (l. c., p. 612). The var. *vulgare*, agreeing with European plants, seems to belong to my ssp. *megalocarpum*, the var. *ciliare*, with longer cilia on the ocreæ, certainly belongs to my ssp. *microcarpum*.

P. subsessile R. Br. var. *typicum* et var. *glabrescens* Dom. (l. c., p. 613).—For varieties founded on different grades of hairiness cf. above *P. orientale*.

P. Dietrichiæ n. sp. (l. c., p. 613). Though I have not seen specimens of this Polygonum, it seems to me to be a new form. I therefore cite Domin's description literatim:—

"1262. *P. Dietrichiæ* n.sp. (Sectio *Persicaria*).

"Perenne, erectum; caulis circa 4 dm. altus, crassiusculus, dense appresse strigosus; folia internodiis longiora, lanceolata, acuminata, circa 8-10 cm. longa et 2–2, 5 cm. lata, sed superiora minora, in pagina superiore breviter densiuscule strigosa, in pagina inferiore sericeo-strigosa et præsertim ad nervos pilis longioribus sericeo-hirsuta; ocreæ mediocriter longæ, mediæ circa 1, 5 cm. longæ, pilis longis densis sursum appressis strigosæ, truncatæ et margine pilis erectis, numerosis ciliisque rigidioribus paucis ocreæ dimidium subæquantibus instructæ; petioli brevissimi, dense strigosi; spicæ longe vel laterales brevius vel brevissime pedunculatæ, nonnullæ vel paucæ in paniculas spurias, laxas, plerumque terminales dispositæ, breves, tantum circa 1, 5–3, 5 cm. longæ, sed crassæ et densæ, erectæ; bracteæ late rhomboideæ, appresse strigosæ, margine longeciliatæ; flores magnitudine eos P. subsessilis æquantes, pentameri; perianthii segmenta 5 petaloidea (in vivo, ut videtur, albida), rotundato-ovata, glabra et eglandulosa ; stamina 5 ; antheræ parvæ, lineari-oblongæ, circa 0, 45 mm. longæ ; stylus paulo supra medium in ramos 2 divisus ; achænia non visa.

" Queensland.—Angeblich Brisbane River, A. Dietrich. No. 1495, 1338.

" Species quasi inter *P. subsessile* R. Br. et *P. articulatum* R. Br. intermedia, a *P. articulato* indumento, petiolis perbrevibus et imprimis ocreis longiuscule ciliatis distinguenda, a *P. subsessili*, cui parte vegetativa propius accedit, primo aspectu spicis brevibus, crassis densisque differt. Forsam forman hybridam *P. subsessile* × *articulatum* exhibet."

(*P. subsessile* probably is my *P. minus subsessile*, *P. articulatum* probably is my *P. attenuatum.*)

P. strigosum R. Br. var. *glabratum* Dom. (l. c., p. 614).—This variety seems to belong to *P. prætermissum* or to *P. dichotumum*, but the description given by Domin does not permit to decide upon this. The almost entire lack of prickles reminds of *P. dichotomum*, the " spicæ gracillimæ" of *P. prætermissum*, whilst the form of the leaf as described occurs in both species.

LITERATURE CITED.

1. Bailey, F. M.—A synopsis of the Queensland flora (1883).
2. Bailey, F. M.—Noxious weeds, Climbing Buckwheat (*Polygonum Convolvulus*). " The Queensland Agricultural Journal," VII., p. 441, t. LX. (1900).
3. Bailey, F. M.—The Queensland Flora, IV. (1901).
4. Bentham, G.—Flora australiensis, V. (1870).
5. Bentham, G., and J. D. Hooker.—Genera plantarum, III. (1883).
6. Blume, C. L.—Bijdragen tot de flora van Nederlandsch Indië, 11de stuk (1825.)
7. Brown, R.—Prodromus floræ Novæ Hollandiæ et Insulæ Van Diemen (1810), ed. 2, quam ad fidem exempli prioris editionis . . . . curavit Nees ab Esenbeck, vol. I. (1827).
8. Danser, B. H.—Contribution à la systèmatique du Polygonum lapathifolium. Recueil des travaux botaniques néerlandais, XVIII., p. 125–210, t. I.–III. (1921).
9. Danser, B. H.—Die Polygonaceen Niederländisch-Ostindiens. Bulletin du Jardin Botanique de Buitenzorg, sér. III., VIII., p. 117–261 (1927).
10. Hooker, J. D.—Flora Novæ-Zelandiæ, I. (1853).
11. Hooker, J. D.—Flora Tasmaniæ, I. (1860).
12. Hooker, J. D.—Flora of British India, V. (1890).
13. Linnaeus, C.—Species plantarum, ed. 1, I. (1753).
14. Meisner, C. F.—Synopsis Polygonearum, quarum specimina exstant in Herbario amplissimæ Procurationis Brittannicæ Indiæ Orientalis, nunc Societatis Linneanæ Londinensis ; in Wallich, Plantæ asiaticæ rariores, III., p. 53-65 (1832).
15. Meisner, C. F.—Polygonceæ, in de Candolle, Prodromus systematis universalis regni vegetabilis, XIV., p. 1–186 (1856).
16. Meisner, C. F.—Polygonaceæ, in F. A. G. Miquel, Annales Musei Botanici Lugduno-Batavi, II., p. 55-65 (1865).
17. Roxburgh, W.—Flora indica, reprinted literatim from Carey's edition of 1832 (1874).
18. Sprengel, C.—Caroli Linnæi Systema Vegetabilium ed. XVI., II., 1 (1825).
19. Willdenow, C. L.—Caroli Linnæi Species Plantarum ed. IV., II., 1 (1799).

The Anatomy of the Australian Bush Nut (Macadamia ternifolia).

By W. D. Francis, Assistant Government Botanist, Brisbane.

With Plate I, and Ten Figures in the Text.

(*Read before the Royal Society of Queensland, 28th May,* 1927.)

Contents.

Introduction.
The Pericarp.
The Testa and Tegmen.
The Embryo.
Comparison with other Proteaceous Seeds.
Summary.

Introduction.

The purpose of this paper is to describe briefly the anatomy of the edible nut produced by *Macadamia ternifolia* F. v. M., a Proteaceous tree of Eastern Australia. In addition to the structural features, the qualitative composition of parts of the nut, as indicated by the application of microchemical tests, will be outlined. A brief description of the structure of the pericarp enclosing the nut will also be given. With this inclusion the paper comprehends an account of the fruit of the species.

The Australian bush nut is the product of one of the few indigenous fruits which have been found palatable by civilised man. It is a commercial article in the capital cities of New South Wales and Queensland. The tree is cultivated to a limited extent in New South Wales for the nuts as a marketable product. The species occurs naturally in the rain forests of Northern New South Wales and parts of Southern Queensland. Its distribution in latitude is confined between 25° S. and 32° S. According to present records its distribution in Queensland does not exceed 100 miles inland from the coast. The species is more commonly known in this State as the Queensland nut tree.

A considerable amount of confusion exists in the descriptions of the fruit in systematic, botanical literature. F. v. Mueller [8] describes the original, genuine fruit of the species as possessing a horny pericarp with a somewhat swarthy, smooth exterior and a very smooth, yellow and date-brown interior. He describes the seed as carinulate near the hilum and the testa as pale, very thin and membranous. Bentham and Hooker [4] describe the fruit of the genus as a subglobose, indehiscent drupe (" Drupa subglobosa, indehiscens") with a fleshy exocarp and a thick, hard endocarp. *Macadamia ternifolia* is the type of the genus. Bentham [3] describes the fruit of the genus as indehiscent with a hard, thick putamen and a rather thin, fleshy exocarp. He also refers to the testa as membranous. Engler [5] describes the fruit as a drupe with a fleshy outer layer and a thick hard inner layer. These authors have misinterpreted the structure of the fruit. Their specimens might have been imperfect. Actually it is a follicle, which dehisces at the suture on one side. The dehiscence often takes place in fruits which are only half developed. The most prominent feature of the fruit is the extraordinary development of the testa, which in some varieties attains a thickness of 5 mm. and requires a great amount of pressure to fracture it. The very hard testa is the chief obstacle to the extensive sale of the nuts. The entire fruit is globose and slightly oblique (Text-figs. 3, 4, 6, and 7).

The Pericarp.

The pericarp consists of two parts, which are readily separable by mechanical means : an outer, fibrous part and an inner, soft part (Text-figs. 3, 4, 6, and 7). The outer part is from twice to thrice as thick as the inner one, as shown in the Text-figures. Externally it is smooth and green and is invested by a cuticle. The epidermis consists of a single layer of very small cells, and, passing inwards, is succeedeed by chlorophyllous parenchyma, the inner cells of which are much larger than those of the epidermis. The remaining tissue consists of branching vascular bundles embedded in the parenchyma. In transverse-radial sections the larger bundles are cut transversely and are situated near the junction of the outer and inner layers of the pericarp (Fig. 2, Plate I.). The smaller bundles branch outwards from the larger ones and are cut longitudinally or obliquely (Fig. 1, Plate I., Text-figs. 1 and 2). The vessels included in the bundles are very fine ones with spiral thickenings.

Text-fig. .

Text-fig. 2.

Text-fig. 1.—Part of outer, fibrous layer of pericarp laid open, showing the branching vascular bundles which traverse it on the inner side. Natural size.

Text-fig. 2.—Section cut along a branch of a large vascular bundle, showing the vascular ramifications extending outwards towards the surface of the pericarp. A, surface of pericarp ; B, branch of large vascular bundle. × 2½.

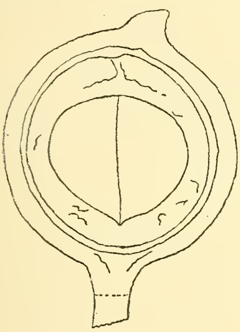
The inner layer of the pericarp consists entirely of soft parenchyma and is represented in the lower part of Fig. 2, Plate I.

The peculiar odour sometimes associated with cyanogenetic tissues was noticed while handling sections of the pericarp. Pieces of the tissue were submitted to Mr. E. H. Gurney, Assistant Agricultural Chemist, who tested them with Guignard's sodium picrate paper and obtained a fairly strong, positive reaction indicating the presence of a cyanogenetic glucoside.

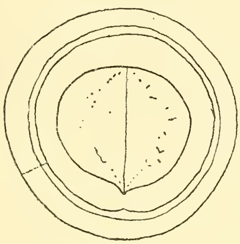
Sections of the tissue were treated by the writer with a 3 per cent. aqueous solution of mercurous nitrate as applied by K. Peche [9] in the localisation of hydrocyanic acid in *Prunus Laurocerasus*. The resulting deposit of metallic mercury indicated the presence of a cyanogenetic glucoside or labile compound in isolated parenchymatous cells of the outer and inner parts and in a fairly continuous single layer of cells in the outer part where it is united with the inner part.

The Testa and Tegmen.

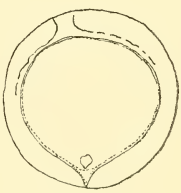
The shell of the nut, which Mueller [8] referred to as a horny pericarp and Bentham [3] as a hard, thick putamen, is designated in this paper as the combined testa and tegmen. To justify this departure from the terminology of Mueller and Bentham it is necessary to show that the parts designated as testa and tegmen are the outer and inner coats of the seed. The ovary contains two suspended ovules attached near its apex. In most cases only one of the ovules matures and a fruit containing a single globose seed is produced as shown in Text-figs. 3 and 4. The remaining undeveloped ovule forms an insignificant, hard, lignified body attached to the inner, upper part of the pericarp ; or, less frequently, it adheres to the surface of the integument of the matured ovule. Much less frequently the two



Text-fig. 3.



Text-fig. 4.



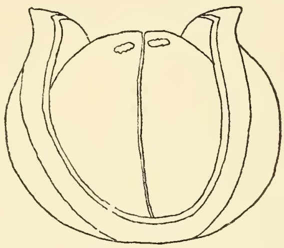
Text-fig. 5.

Text-fig. 3.—One-seeded fruit sectioned longitudinally in same plane as the opening suture of pericarp. The two layers of the pericarp are shown. The thick testa with a few irregularly sectional vascular bundles surrounds the cotyledons which are shown as divided longitudinally. Two vascular bundles indicate the region of the hilum below the stylar projection. Natural size.

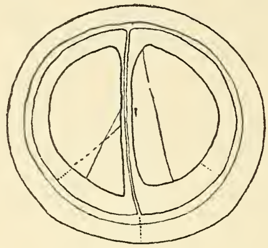
Text-fig. 4.—One-seeded fruit sectioned transversely. The opening suture of the pericarp is indicated by the dotted line on left. In the lowermost part of the figure the testa is shown as thinner than elsewhere. This part is situated on a line joining the hilum and micropyle. Transversely and obliquely cut vascular bundles are indicated in the cotyledons. Natural size.

Text-fig. 5.—Section of seed cut longitudinally along the line joining the hilum and micropyle. The position of the hilum is indicated by the two vascular bundles on the upper, left side. The position of the pale part of the tegmen is indicated by the dotted line, and the dark-brown part is represented diagrammatically by the continuous line. The plumule and radicle are situated just above the micropyle, the radicle pointing downwards towards the micropyle. The tegmen is strongly thickened in the region of the micropyle. Natural size.

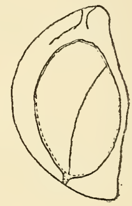
ovules mature and the fruit contains two hemispherical seeds as shown in Text-figs. 6 and 7. The hard shell consists of the coats of the fertilised and matured ovule and is, therefore, the testa and tegmen. In very young fruits the existence of two layers or integuments is clearly demonstrable in the tissue which develops into the hard shell. In mature fruits the



Text-fig. 6.



Text-fig. 7



Text-fig. 8.

Text-fig. 6.—Two-seeded fruit. The two parts of the pericarp are shown. The two seeds, exposed by the opening of the pericarp, are shown in the middle of the figure. The two hila of the seeds are shown in the upper part. Natural size.

Text-fig. 7.—Transverse section through a two-seeded fruit. The dotted line through the pericarp on the lower side represents the opening suture. The dotted lines through the testa on each side indicate the position of the line along which the testa splits in germination. The interrupted line passing through the two cotyledons of the seed on the left marks the plane through which the seed represented in text-fig. 8 was sectioned. Natural size.

Text-fig. 8.—A seed of a two-seeded fruit cut longitudinally in the direction indicated in Text-fig. 7. The position of the hilum is indicated by the vascular bundles near the apex. The dotted line shows the position of the pale part of the tegmen and the continuous line represents diagrammatically the position of the dark-brown part of the tegmen. Natural size.

differentiation into testa and tegmen is very clearly seen in the lower half of the seed (Fig. 4, Plate I.). It will be shown in the part of this paper relating to the comparison with other Proteaceous seeds that the inner, lower portion of the shell of the bush nut and the inner integument of other Proteaceous seeds are homologous. There is no membrane or tissue of any kind between the inner surface of the shell and the epidermis of the cotyledons. In adopting the term of combined testa and tegmen for the hard shell the nut then represents a typical seed with two seed coats, a hilum and micropyle (Text-figs. 5, 6, and 8).

The hilum is lateral and situated towards the apex of the seed. It is irregularly rounded or oval in outline and varies in width from 3 to 8 mm. It is united with the pericarp near the opening suture and towards the stylar projection (Text-figs, 3, 5, 6, and 8). The micropyle is situated towards the lower end of the seed, as shown in Text-figs. 5 and 8. In the vicinity of the micropyle the testa is deficient and the tegmen extends outwards towards or as far as the surface of the testa. Along a line joining the micropyle and hilum the testa in one-seeded fruits is thinner than elsewhere (Text-fig. 4). The tissue of the testa contains a natural fissure along this line near the micropyle. The fissure in one-seeded fruits is in the same plane as the division between the cotyledons. When germination takes place the testa splits along this line and fractures on the other side, forming two hollow hemispheres, each of which loosely envelops a cotyledon.

The combined testa and tegmen vary in thickness in different trees from 2 to 5 mm. By far the greater part represents the testa, as the tegmen only measures about ·25 mm. in thickness. The testa is very hard. The sections of it represented in Figs. 3 and 4, Plate I., were cut from pieces immersed in strong hydrofluoric acid for seven months. The tissue consists of sclerenchyma, which is traversed by occasional vascular bundles. The vessels of the bundles are very fine ones with spiral thickenings. The sclerenchyma consists of cells with stratified and pitted walls. The superficial cells are flattened and possess narrower lumina than the internal ones. Maceration of the tissue effected by nitric acid and potassium chlorate (Schultze's method) releases a great diversity of cell shapes varying from narrow, fibre-like cells $640\mu \times 16\mu$ to irregularly rounded and flattened ones about 64μ in diameter. The elongated forms predominate. Angular, branched, rostrate and sinuous forms among the separated cells indicate a high degree of interlocking, which contributes to the rigidity of the tissue. The walls of the cells, when treated with 5 per cent. alcoholic phloroglucin and mounted in strong hydrochloric acid, assume an intense reddish-violet colour indicating lignification. In untreated sections the cells are filled with a dense, apparently colloidal substance varying in colour from bright reddish-brown to yellow. This substance may be phlobaphene as described by Molisch [7], who states that there is no specific microchemical test for it. In many of the cells parts of this substance assumed a bluish-black colour with solutions of ferric chloride and iron-ammonium sulphate suggesting the presence of tannin. This reaction supports the assumption that the cell contents may be phlobaphene, which is derived from tannin.

The tegmen or inner seed coat forms a smooth, shining, tenuous layer on the inside of the testa with which it is united. It consists of two kinds of tissue which are widely different in appearance. In the lower half it is white or pale yellow and enamel-like. The position of this part is indicated by the dotted line in Text-figs. 5 and 8. In the upper half it is dark brown and shining. F. v. Mueller's description [8] of the interior of the part designated by him as the pericarp refers to the colours and smoothness of these two parts of the tegmen. The lower, enamel-like part is abruptly united with the tissue of the testa (Fig. 4, Plate I.). It is composed of hard material and consists of polygonal and rectangular cells which are granular in appearance. These cells are not resolvable by the ordinary microscopic methods into walls and lumina. In each cell at the extremity directed outwards or towards the testa a small, angular, clear area is visible. This clear area evidently indicates a position in the cell occupied by a crystal of calcium oxalate, which appears to have been dissolved either by the treatment involved in the preparation and mounting or by the natural processes of the maturing seed. In young developing fruit these cells possess crystals which are seen to be doubly refracting when viewed between crossed Nicols. The crystals are undissolved by acetic acid but are soluble in hydrochloric acid. It is concluded that they consist of calcium oxalate. In the mounted sections of the tegmen of mature seeds the angular, crystal-like areas are not very sharply defined and remain dark between crossed Nicols. Cells with similar crystals located in the same part of the cells will be described further on as constituting the tegmen of other Proteaceous seeds. The granular material, which appears to be the sole constituent of the cells, with the exception of the crystals, is apparently unstratified. That it is a hard substance is evident from the mechanical properties of the whole tissue. When viewed between crossed Nicols it is seen to be doubly refracting, which is a physical property of cell-wall material. With chlorzinc iodide it turns blue in the same manner as cellulose does. With iodine (dissolved in potassium iodide) and sulphuric acid it turns brown, which is one of the colour reactions of lignified tissue. With phloroglucin and hydrochloric acid it assumes a dense reddish-violet colour, which is another colour reaction of lignified tissue. It is insoluble in strong sulphuric acid, indicating that it differs from cellulose in solubility. These reactions indicate that the granular material is a ligno-cellulose.

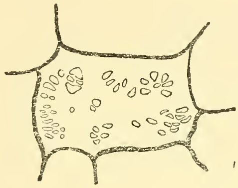
The upper, brown part of the tegmen is continuous with the testa. It is composed of smaller and more regular cells than those forming the testa. The whole of the tissue of this part of the tegmen is deeply impregnated with a dark-brown substance, possibly phlobaphene, which renders it almost opaque, even in thin sections (Fig. 4, Plate I.).

The Embryo.

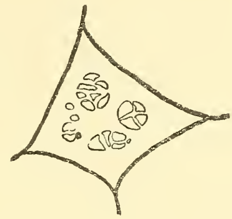
In one-seeded fruits the embryo is subglobose and the cotyledons large and semiglobose. The radicle and plumule together form a small, subglobose body which is acuminate at the lower or radicular end ; they are inserted between the cotyledons at the lower end (Text-fig. 5). Text-figs. 3, 4, and 5 show the outline of the cotyledons in a one-seeded fruit, and Text-figs. 7 and 8 represent it in a two-seeded fruit. At the lower end in the vicinity of the radicle each cotyledon is divided. When germination takes place this small division forms the sinus between the two basal auricles, which are situated, one on each side of the petiole, at the base of the cotyledon.

The epidermis of the cotyledons consists of relatively small cells containing nuclei and diffused protoplasm without granules or the bodies subsequently referred to as proteinoplasts. The internal tissue of the cotyledons consists of parenchyma traversed by a few vascular bundles consisting largely of very fine, spiral vessels. The perforation of the parenchymatous cells consists partly of rounded openings and partly of somewhat elongated or slit-like apertures in the secondary wall (Text-fig. 9). Some of the apertures are arranged in round or elliptical groups each of which is probably related to an adjoining cell. The walls of the epidermal cells of the radicle and plumule are decidedly thicker than those of the internal tissue, which consists of exceedingly thin-walled cells containing nuclei and abundant, finely granular protoplasm. The breadth of the internal cells of the plumule and radicle is approximately one-third that of the internal cells of the cotyledons. The prominent proteinoplasts of the cotyledonary tissue are absent from the tissue of the plumule and radicle.

When sections of the cotyledons, which are freed from oil by treatment with ether, are acted upon by strong sulphuric acid the cellulose walls are dissolved and the cutinised walls of the epidermis remain. When fresh sections are immersed in equal parts of a 1 per cent. alcoholic solution of Sudan III. and pure glycerine and heated on a slide until the alcohol boils,



Text-fig. 9.



Text-fig. 10.

Text-figs. 9 and 10.—Cells of internal tissue of cotyledon, showing the apertures of the cell walls. × 500.

the cutinised walls of the epidermis and the oil in the cells are stained red. With this method, which is recommended by Lee and Priestley [6], the cutinised walls stain a deeper red than the oil, whilst the cellulose remains colourless. Fig. 5, Plate I., is a photograph of a preparation stained in this way. The photograph shows the darkly-stained, cutinised walls of the epidermis on the exterior of the cotyledons and the cutinised outer walls of the epidermal cells where the cotyledons are in contact.

Smith and Meston [11], who analysed the embryo, found it to contain 66 per cent. oil, 8·8 per cent. protein, 15·4 per cent. carbohydrates, 5·1 per cent. crude fibre, and 1·7 per cent. ash. The writer studied the distribution of the oil by staining sections with Sudan III. and by submitting sections to solubility tests with ether, chloroform, and absolute alcohol. The application of these methods indicated that the oil is contained in all of the non-vascular cells of the embryo. The distribution of the protein was investigated with Millon's reagent, the xanthoproteic reaction, Raspail's test and solubility in 2–5 per cent. aqueous solutions of potassium hydroxide. Sections of the cotyledonary tissue, which were freed from oil with ether and treated with absolute alcohol, when submitted to these tests indicated that the protein in a granular or diffused state is also fairly generally distributed in the non-vascular cells. A large amount of the protein is contained in leucoplasts in the internal tissue of the cotyledons. These leucoplasts contain mostly one, but sometimes two, three, or four round or partly compressed protein grains (Fig. 6, Plate I.). The body of the leucoplast as well as its contained protein grains stains red with Millon's reagent and dissolves in ·5 per cent. aqueous potassium hydroxide. It was noticed that the protein grains often dissolved first, indicating their greater solubility in the reagent. When examined between crossed Nicols a very small numerical proportion of the protein-containing leucoplasts showed a minute doubly refracting crystal, possibly of calcium oxalate. The absence of the globoid, which is so frequently found in the protein grains of oily seeds, is indicated by the solubility of the protein-containing bodies in the very dilute alkali. Molisch [7, p. 371] illustrates apparently similar bodies from the milky sap of *Cecropia peltata* and refers to them as "Proteino-(Leuko-)plasten" or "Proteinoplasten." He states [7, p. 372] that according to Wakker and Werminski the protein grains of seeds originate from vacuoles, that the aleurone grains are originally vacuoles filled with protein and that they become solid with the drying of the ripe seed. Schneider and Zimmermann [10] also figure somewhat similar bodies in the epidermis of the upper side of the leaf of *Tradescantia discolor*. They refer to them as leucoplasts and to the protein inclusions as leucosomes. It appears from this investigation that the protein grains of the cotyledonary tissue of *Macadamia ternifolia* are developed in leucoplasts. As leucoplasts are differentiated portions of the protoplasm and are regarded as cell organs, apparently the protein grains in this instance have a different origin from that ascribed to the aleurone grains of seeds by Wakker and Werminski.

Comparison with other Proteaceous Seeds.

The structure of the seeds and pericarps of *Macadamia Lowii* F. M. Bailey and *M. minor* F. M. Bailey is similar to that of the seed and pericarp of *M. ternifolia*, but their fruits are only about half the size of the fruits of *M. ternifolia*. The seeds of *M. Whelani* F. M. Bailey have a very thick, hard testa which is expanded into a large disk on the inner, lower side. The disk has a funnel-shaped aperture in the middle through which a slender, tapering part of the embryo passes downwards to the micropyle. The broad, upper part of the cotyledons rests upon the disk and overlaps its summit. A very thin, pale yellow tegmen invests the surface of the disk. The upper part of the tegmen is a thin, loose, dark-brown coat lining the inner surface of the testa above the disk. In two-seeded fruits the inner part of the pericarp is extended between the seeds as a dissepiment, a structure which is lacking in *M. ternifolia*. The fruit of *M. Whelani* is about twice the size of that of *M. ternifolia*. The one remaining species included in *Macadamia* by F. M. Bailey [2], the ball nut, *M. prœalta* (*Helicia prœalta* F. v. M.) has an indehiscent pericarp and two semiglobose or one globose seed with two separable, papery seed coats. The fruit is about twice the size of that of *M. ternifolia*.

The testa in *Grevillea Banksii* R.Br. is composed of thin-walled parenchyma. The tegmen is constructed of a single layer of radially elongated, granular cells with a single crystal of calcium oxalate situated at the outermost extremity of each cell. The tissue composed of these cells and the tegmen in the lower part of the seed of *Macadamia ternifolia* are evidently homologous. The fruit of *Grevillea Banksii* is a follicle containing two winged seeds.

The tegmen is the only continuous coat investing the seeds of *Banksia collina* R.Br. The cells constituting it each contain a prominent crystal of calcium oxalate at the outer extremity. The crystals frequently have the appearance of prominent, outward extrusions from the cell walls. After prolonged action of strong hydrochloric acid the forms of the crystals remained, but they had lost their doubly refracting property. In preparations treated with strong acetic acid for the same time the crystals retained their birefringent effect. Apparently the crystals are intimately encrusted by a substance insoluble in hydrochloric acid. An envelope surrounding crystals of calcium oxalate has been observed by Alexandrow and Timofeev [1] in the wood of *Sterculia platanifolia*. These authors state that the envelope is probably composed of cellulose. Bentham [3, p. 540] states that Brown has pointed out that the plate intervening between the two seeds in the Tribe Banksieæ consists of the outer coating of one side of each seed, and that these outer coats forming the dividing plate separate from the inner ones and become united at the base but remain separate in the upper part of the plate. The seeds of *Banksia collina* when detached from this intervening plate are enveloped by a coat which evidently corresponds to the tegmen in the lower part of the seed of *Macadamia ternifolia*.

Summary.

The Australian bush nut is a seed. The fruit in which it is contained is a follicle and the thick hard shell of the nut is the combined testa and tegmen. Hitherto the fruit was described as a drupe and the shell of the nut as an endocarp or putamen. The pericarp consists of an outer fibrous part and an inner parenchymatous part. The tissue of the testa is very rigid and consists of thick-walled, lignified cells varying in shape from narrow fibre-like cells to flat broad ones, the elongated forms predominating.

The lower part of the tegmen or inner coat of the seed is a tenuous layer of white, enamel-like, hard material consisting of polygonal and rectangular cells. These cells in appearance are granular ; they are without evident lumina ; and their walls are apparently unstratified. Their granular material on the application of microchemical tests yields reactions indicative of a ligno-cellulose. In prepared and mounted sections each of these granular cells exhibits a small, angular, clear area marking the position occupied by a crystal of calcium oxalate which apparently has been dissolved. The upper part of the tegmen is a very thin, brown layer composed of smaller and more regular cells than those of the testa. Its cells are deeply impregnated with a dark-brown substance, possibly phlobaphene, which renders them almost opaque, even in thin sections.

The internal tissue of the plumule and radicle is differentiated from that of the cotyledons by its thin-walled, much smaller cells containing conspicuous nuclei and abundant, finely granular protoplasm, properties adapted to its physiological functions as generative tissue. The internal cells of the cotyledons are characterised by the possession of numerous protein-containing bodies or proteinoplasts, which qualifies them for the rôle of storage. The large quantity of oil contained in the embryo is distributed throughout its non-vascular cells. The protein of the embryo is also fairly generally

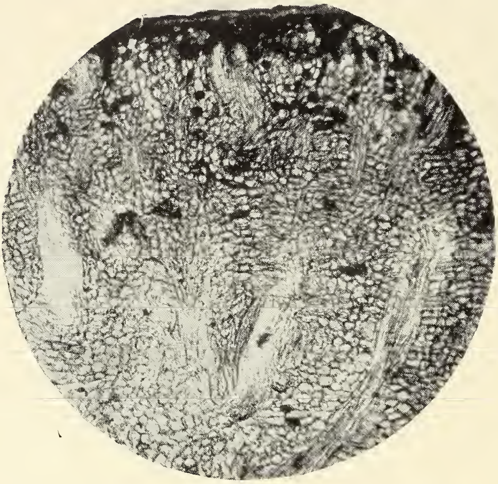
distributed in the non-vascular tissue. The protein grains of the proteinoplasts apparently originate in a different way from that ascribed to the aleurone grains of seeds by Wakker and Werminski.

The seeds of the other species of *Macadamia* are compared with those of *M. ternifolia*. A tegmen consisting of cells, each of which contains a crystal of calcium oxalate, is also a feature of the seeds of *Grevillea Banksii* and *Banksia collina* of the Natural Order Proteaceæ. The occurrence of this kind of tissue in the inner seed coats of these widely separated species suggests that a similar tegmen may be characteristic of the Natural Order or a large section of it.

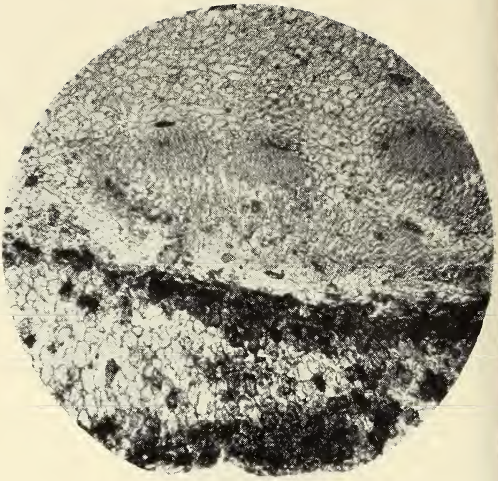
Acknowledgments.—The writer is indebted to Mr. C. T. White (Government Botanist) for permission to use some of the specimens in the Botanic Museum, Brisbane; to Mr. E. W. Bick (Director, Botanic Gardens, Brisbane) for supplies of fresh fruit; and to Mr. J. C. Brunnich (Agricultural Chemist) and his staff for some of the reagents used. Appreciative acknowledgment is also expressed to Mr. H. Tryon, who drew the writer's attention to the presence of crystals in the inner seed coat of *Grevillea Banksii* and who supplied fruits of *Banksia collina*.

REFERENCES.

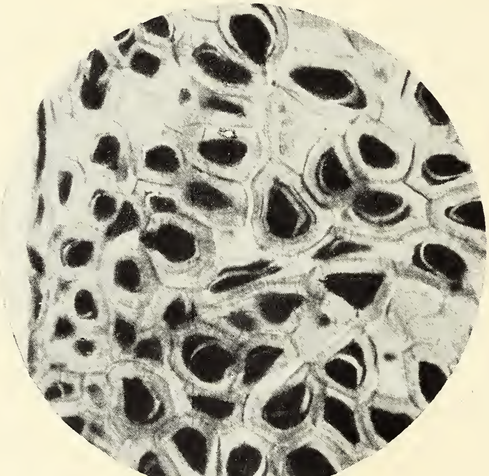
1. ALEXANDROW, W. G., and A. S. TIMOFEEV.—Ueber die Losung des kristallischen Calciumoxalats in den Pflanzen. Botanisches Archiv., XV., 286, 1926.
2. BAILEY, F. M.—The Flora of Queensland, IV., 1330, 1901.
3. BENTHAM, G.—Flora Australiensis, V., 406, 1870.
4. BENTHAM, G., and J. D. HOOKER.—Genera Plantarum, III., 178, 1883.
5. ENGLER, A., in Engler und Prantl's Die naturlichen Pflanzenfamilien, III., Teil, I., Halfte, 147, 1894.
6. LEE, BEATRICE, and J. H. PRIESTLEY.—The Plant Cuticle, I. Annals of Botany, XXXVIII., 528, 1924.
7. MOLISCH, HANS.—Mikrochemie der Pflanze, Zweite Auflage, 176, 1921.
8. MUELLER, F.—Fragmenta Phytographiæ Australiæ, VI., 191, 1867–1868.
9. PECHE, K.—Mikrochemischer Nachweis der Cyanwasserstoffsäure in Prunus Laurocerasus L. Sitzungsber. der Kaiserl. Akad. der Wissenschaften in Wien, Bd. CXXI., Abt. 1, 33–55, 1912.
10. SCHNEIDER, HANS, and A. ZIMMERMANN.—Die Botanische Mikrotechnik, Zweite Auflage, 345, 1922.
11. SMITH, F. B., and L. A. MESTON.—Some Oil-bearing Seeds indigenous to Queensland. Proc. Roy. Soc. Queensland, 26, 16, 1914.



1. Outer part of pericarp. Transverse-radial. × 40.



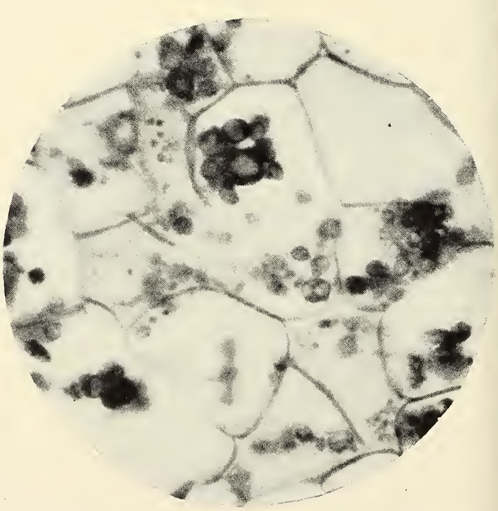
2. Inner part of pericarp. Transverse-radial × 40.



3. Outer part of testa. Longitudinal-radial. × 170.

4. Tegmen and inner part of testa. Longitudinal-radial. × 100.

5. Part of the two cotyledons. Transverse. × 170.



6. Tissue of cotyledon, showing proteinoplasts. × 380.

Face page 53.]

EXPLANATION OF PLATE.

Figs. 1, 2, and 4 were photographed with a 16 mm. apochromatic objective N.A. ·3; and Figs. 3, 5, and 6 with a 4 mm. apochromatic objective N.A. ·95. Compensating eyepiece 4 was used for Figs. 1, 2, 3, and 5, and compensating eyepiece 8 for Figs. 4 and 6.

1. View of transverse-radial section, showing outermost part of pericarp, stained with Heidenhain's iron hæmatoxylon and Safranin. The outermost dark band is the cuticle; beneath it the fine, light band represents the small-celled epidermis. Obliquely cut vascular bundles traversing parenchyma are the chief features of the picture.

2. View of the innermost part of the same preparation, which is partly shown above. The upper part shows the inner portion of the fibrous layer and three large vascular bundles in transverse section surrounded by parenchyma. The lower part of the picture depicts the entire width of the parenchymatous inner layer of the pericarp, which is separated from the outer layer by the cells with dark contents situated towards the middle of the picture.

3. Longitudinal-radial section through combined testa and tegmen stained as in previous section. The outer, covering layer of compressed cells is depicted on the left. The lignified walls, abundantly pitted, and the cell inclusions are shown. This view is limited to the outermost part of the testa.

4. View of innermost part of same preparation, which is partly shown in Fig. 3. The innermost part of the testa and the junction of the lower and upper parts of the tegmen are shown. The reddish-brown or yellow contents of the cells of the testa are shown on the right. The granular cells of the lower part of the tegmen are shown on the left. The small, light areas marking the positions once occupied by crystals of calcium oxalate are indistinctly seen in the cells of the lower part of the tegmen. The very dark part of the picture on the upper left side represents the upper, dark-brown part of the tegmen, which is almost opaque. The dark-brown part of the tegmen is shown overlapping the lower, pale part. This thin overlapping part is non-cellular.

5. Section of part of two cotyledons, slightly obliquely cut, heated on a slide with equal parts of 1 per cent. alcoholic solution of Sudan III. and pure glycerine. The cutinised walls of the epidermal cells on the outside of the cotyledons and the cutinised outer walls of the epidermal cells between the coytledons are deeply stained. In contrast the cellulose walls of the internal tissue are unstained. The oil present in the cells almost throughout the tissue is stained by the reagent.

6. Section of internal tissue of cotyledon fixed with Carnoy's fluid and stained with Heidenhain's iron hæmatoxylon. The proteinoplasts are focussed in some of the cells. Towards the middle of the picture one proteinoplast with two protein grains is shown. The body of the proteinoplasts has stained more deeply than the contained protein grains.

Volcanic Mud Balls from the Brisbane Tuff.

By H. C. RICHARDS, D.Sc., and W. H. BRYAN, D.Sc.

Plates II. and III.

(*Read before the Royal Society of Queensland, 25th July, 1927.*)

I. INTRODUCTION.

At a meeting of this Society, held on 27th July, 1925 [1], the authors exhibited specimens of Brisbane tuff from Castra, on the right bank of the Tingalpa Creek and 12 miles east-south-east of Brisbane. One of the reasons for bringing the exhibit before the notice of the members of the Society was the presence, in some portions of the tuff, of numerous small rounded bodies, the mode of origin of which was an enigma to the exhibitors. The authors hoped that some reasonable explanation of these bodies might have been advanced at the meeting, but none was forthcoming.

Although the Brisbane tuff has been closely examined in many of the quarries and natural sections in and about Brisbane by numerous observers, no bodies like those of Castra have ever been found elsewhere.

II. DESCRIPTION.

The geological section at Castra shows a thickness of approximately 30 feet of consolidated volcanic ash almost horizontally disposed, very similar to the "Brisbane Tuff" of Upper Triassic age, which is typically developed in and about the City of Brisbane. The tuff lies unconformably over the Brisbane Schist series. At the base of the tuff numerous angular and subangular fragments derived from the schists, together with angular blocks of rhyolite, some at least 6 inches across, are embedded in the tuff. These probably represent a volcanic agglomerate, although many of the fragments of schist may be remnants of the old land surface.

The spheroidal bodies which form the subject of this paper occur scattered throughout the lower and middle portion of the section of tuff.

1. Abstract of Proceedings Roy. Soc. Qld., 1925, Vol. XXXVII., p. xii.

Plate II. B gives an idea of the average proportion of the spheroids to the ordinary tuffaceous groundmass. There is, however, a tendency for the balls to collect on certain layers, some strata being almost crowded with them, as in Plate II. A. Again, even in comparatively barren strata, "nests" of spheroids occur. In the upper portion of the section the balls are more sparsely distributed and the individuals are considerably smaller, while in the uppermost portion of the section none were found.

Owing to the superior weather-resisting properties of the balls as compared with the tuffaceous groundmass they are to be found in considerable numbers lying on the surface and at the bottom of the slope of the outcropping tuff.

In size the balls exhibit considerable variation, but for the most part they can be compared with marbles and beads. In addition to the variation in size of individuals from any one horizon is the fact already noted that the balls from the upper portion of the tuff are considerably smaller than those below.

The largest spheroids found were a small group, the individuals of which measured 25–30 mm. in greatest diameter. In addition to their unusually large size these differed in other respects from the typical spheroids and must be regarded as distinctly abnormal (see Plate III.). About 300 balls were collected *in situ* from the tuff in the middle of the section. These, when separated by sieves with meshes of 11, 9, 6, and 4 millimetres respectively, showed the following proportions and sizes:—

GROUP A.	GROUP B.	GROUP C.	GROUP D.	GROUP E.
+ 11 mm.	− 11 + 9 mm.	− 9 + 6 mm.	− 6 + 4 mm.	− 4 mm.
20	74	204	8	0

A separation of material obtained from a restricted spot in a somewhat lower portion of the section gave the following results:—

A.	B.	C.	D.	E.
22	41	105	0	0

Practically all the specimens collected from the higher part of the section belonged to Group D.

Although there are some specimens approaching true spheres, some which are egg-shaped, and others of less regularity, the vast majority may be described as spheroids. The ratio in length between the long axes and the corresponding short axes is not uniform, some of the balls being much flatter than the others. When examined *in situ* a noticeable fact is that the short axes are perpendicular to the bedding planes of the tuff. This suggests that the balls were originally spherical in shape and acquired the flattening after falling into position as a result of the pressure of the sediments which were afterwards added to the series.

Internally the only structure of the spheroids is seen to be concentric, although some specimens are so homogeneous that no structure whatever is discernible. The concentric structure is, however, plainly shown in many individuals, and is often intensified as the result of differential weathering or colouring of the several zones. (See Plate III. E.) One very common feature is the presence of a skin of material with a glazed surface and frequently different in colour from the remainder of the specimen. It is this hard outer skin which makes the spheroids so resistant to weathering.

Lithologically the material of the balls appears to be not dissimilar from that of the enclosing volcanic tuff, except that it is of much finer grain. A micro-section of a typical ball shows the material to be very fine and to resemble a clay in texture, the outermost portion, however, being noticeably more compact than the interior. Observation by the unaided eye shows, however, that many specimens are made up of somewhat coarser material.

The authors considered the advisability of procuring chemical analyses of the spheroids with a view to determining whether they were tuffaceous in nature. The expenditure entailed in time and money on such analyses was, however, thought to be unwarranted for the following reasons:—

(1.) The difficulty of deciding on a really representative sample of such a heterogeneous rock as a tuff for purposes of comparison;

(2.) The differential effects of subsequent alteration of the tuff and the included balls, protected as the latter are by their glazed skins;

(3.) Even if both tuff and balls had the same source of origin, it could not be safely assumed that they would be closely similar chemically owing to their different grades of comminution and to the sorting action of gravity on slowly falling dust-like particles.

III. Comparisons.

A. *Philippine Islands.*—Recently the authors met with the description of apparently identical tuff balls, together with a feasible explanation of their origin, in an article under the caption "An Unusual Form of Volcanic Ejecta." [2] The author of the article (Wallace E. Pratt) described "small concretion-like bodies in the finest grained portion of the blanket of fragmental ejecta" thrown out during the disastrous eruption of Taal Volcano in south-western Luzon, Philippine Islands, during the month of February, 1911. Taal Volcano forms an island near the centre of a lake from 15 to 20 kilometres in diameter, and the mud balls were found both on the slopes of the volcano and on the outer margin of the lake. Pratt's description of the mud balls of Taal is as follows:—" . . . drops or balls of mud . . . They range in

2. Journal of Geology, 1916. Vol. XXIV., p. 450.

size from large shot to hazel nuts, and when broken sometimes show concentric markings.''

Since the eruption of 1911, there have been found by Pratt, at the towns of Bauan and Taal, at depths of from 100 to 150 metres, ''abundant spherical and ellipsoidal inclusions'' which were ''indistinguishable from the mud balls of the last eruption of Taal.'' Pratt also describes, from several widely separated localities in the older tuffs of Luzon ''dating back probably to the late Miocene,'' ''well preserved balls enclosed in clayey tuff'' which ''have retained their form.''

B. *Martinique.*—The only volcanic ejecta known to Pratt which could be regarded as comparable with the mud balls of Luzon were the ''drops of mud'' described by Hovey [3] which fell during the eruptions on Martinique in 1902. But these ''flattened spheroids of mud'' measuring ''2, 4, and 6 inches across where two or more had coalesced'' do not bear nearly so close a resemblance to those of Luzon as do those collected by the authors from Castra.

In size, shape, nature of the material, and type of structure, the mud balls of Luzon are wonderfully like those of Castra. This is shown not only by the descriptions of the former but by several photographic illustrations which accompany them. A comparison of Plates II. and III. of the present paper with Figures 2 and 3 of Pratt's account shows the remarkable similarity.

IV. Suggestion as to Origin.

When the authors first noted the presence of the spheroidal bodies embedded in the tuff at Castra they realised that they could not be referred to any of the usual products of vulcanicity such as lapilli or small bombs. Neither were they Australites nor concretions. Two suggestions presented themselves. The first was that they resulted from a rather unusual type of spheroidal weathering. The fact that the bodies were most obviously displayed in the more weathered portions of the outcrop seemed to support such a view, but closer examination showed their presence in the heart of unweathered and unstained blocks of solid tuff, and another explanation was sought. Superficially, the bodies resembled in shape and size the spherulites which are quite commonly found in rhyolites of various ages in South Queensland, and the fact that they occurred in a tuff which is of an acid nature and is made up largely of minute fragments of rhyolite gave weight to the opinion that the spheroids were spherulites which in some curious way had become isolated from the parent body of rhyolite. This second hypothesis broke down when individual spheroids were sectioned and examined microscopically. It was found that they were essentially concentric in structure and showed no trace of the radial character typical of spherulites. Moreover, the material of which the bodies was formed appeared to be very finely comminuted particles almost like clay in appearance.

3. American Journal of Science, XIV. (1902), 343.

Hovey, in describing the volcanic phenomena at Martinique in 1902, wrote:—

> ''In addition to the showers of dry dust and ashes, there fell during the eruption an immense amount of liquid mud which had been formed within the eruption cloud through the condensation of its moisture. That drops of mud, too, formed in the air and fell as a feature of the eruption is proved . . . '' . . . '' . . . the evidence of the mud coating and these drops of mud proves that much aerial condensation of steam accompanied these outbursts.''

Pratt accepted the explanation of Hovey for the ''mud drops'' of Martinique and thought it quite applicable to the mud balls formed in the 1911 outbursts of Taal. Further, in light of the wide distribution of hardened mud balls in the older tuffs of Luzon, Pratt suggests—

> ''That the condensation of mud into drops or balls must be a rather common feature of volcanic eruptions which throw out great clouds of water-vapour and fine sand or dust,''

and he adds—

> ''The product may be described, perhaps as a volcanic hailstone.''

It is probable that Pratt, in making this interesting comparison, had in mind not the frozen rain drop which is often referred to as hail, but the true ''summer hail'' which precedes thunder showers. Of the formation of the latter, Milham, in his text-book on ''Meteorology,'' writes as follows:—

> ''The hailstones are usually large, in some cases several inches in diameter, and they consist of concentric layers of compact snow and ice . . . The hailstones are formed in the whirling squall-cloud of a thunder shower. The nucleus is carried up and coated with snow; it then falls or is carried down and is coated with water; it is then carried up again; the process continues, adding coat after coat until the hailstone becomes too heavy to be longer sustained, and it falls to the ground.''

As Pratt had the good fortune to study both the mud balls as they lay on the surface soon after the eruption and those resulting from previous eruptions, some probably from the Tertiary era, his explanation must be regarded as carrying great weight. Consequently, and in view of the marked similarity of the Castra spheroids with those of Luzon, the authors see no reason why this explanation should not be applied to the local development.

The suggestion has been made to the authors that the mud balls, after being formed high above the volcano, became dried and hardened in their final descent through the hotter air nearer the volcanic vent, and the outermost parts in particular became glazed and indurated and thus gave the balls sufficient strength to withstand the shock of impact, whether they fell into the water of a Triassic lake or into loose finely-comminuted volcanic ash.

One feature which it seems the volcanic outbursts of Castra and Luzon possessed in common and which may have some bearing on the formation of the balls is their close proximity to large bodies of water.

Thus Taal Volcano stands actually within a lake, and the lake itself is thought by some authorities [4] to mark the caldera of a huge volcano. Of some of the tuffs of Luzon from which mud balls were obtained Pratt states that—

> " . . . it is beyond question that the tuff is in great part water-laid, and it is to be presumed that the mud balls . . . fell into the sea originally."

There is good evidence for believing that the Brisbane tuff is a water-laid volcanic ash, for it is in several places underlain by normal fresh-water lacustrine sediments, while its upper portions pass gradually into felspathic sediments and then into normal shales and sandstones.

V. Possible Climatic Significance.

Pratt is of the opinion that the formation of mud balls is probably confined to those regions "where atmospheric conditions similar to those on the island of Luzon prevail." He points out in support of this conclusion that—

> "Unless conditions peculiar to the tropics, such as high temperature and, perhaps, excessive humidity, are essential factors in the phenomena which have been described, it would appear that mud balls should have been formed in the eruption cloud from Katmai Volcano in Alaska and in the [then] recent eruption of Mount Lassen in California."

In view of the fact that mud balls are a rare form of volcanic ejecta, and of Pratt's suggestion that atmospheric conditions of a tropical nature are the controlling factors, it is of interest to inquire whether the climatic conditions in Southern Queensland during the late Triassic (or Rhætic) time when the Brisbane tuff was ejected may have approximated what we term "Tropical" at the present day. The prolific vegetation which succeeded the eruption as shown by the very numerous fossil plants in the overlying shales of the Ipswich Series, and the numerous coal seams is quite in harmony with such a view.

Seward [5] has emphasised the cosmopolitan nature of the floras of Rhætic and Jurassic times, when little difference existed between the plants of such widely separated places as Greenland, Ceylon, and Antarctica. The suggestion conveyed by this flora is of a uniformly moist and hot climate spreading from pole to pole, for many of the

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4. Tempest Anderson Volcanic Studies, 1917, p. 87.
5. Pres. Add. Q.J.G.S., Vol. 80, 1924, p. xci., *et seq.*

fossil plants of Greenland are similar to those of Malay and India at the present. Seward is, however, careful to point out that other conclusions, based upon the adaptability of plants, are possible.

Thus evidence, both as to the nature of the plants of the Ipswich Series and as to their luxuriance, is for, rather than against, such tropical conditions as Pratt considers necessary for the formation of volcanic mud balls.

VI. Position of Centre of Eruption.

It might be thought that the presence of mud balls at Castra could serve as an indication of the proximity of one of the centres of eruption which ejected the Brisbane tuff, for the nearest other outcrop of the series, some 5 miles to the N.N.W., contains none of these bodies. Such a view is supported by the presence of comparatively large blocks of rhyolite at the base of the tuff.

Basing his opinion on quite other evidence than this, and before the discovery of the tuff and associated balls at Castra, one of us [6] wrote as follows:—

> "It is not unlikely that the source of the activity was to the east or south-east of Brisbane [*i.e.*, towards Castra] in a region now foundered beneath sea-level."

The evidence from Luzon does not, however, lend much support to the idea that these balls indicate the centre of eruption. After the eruption of Taal, Pratt found mud balls from 6 to 8 kilometres distant from the crater, and concluded that they "must have been widely distributed." Some older specimens, obtained 25 kilometres away, Pratt thinks "may have come from Taal itself."

DESCRIPTION OF PLATES.

Plate II.

Photographs of hand specimens of tuff, showing the arrangement of volcanic mud balls in their matrix.

Plate III.

Individual mud balls arranged in series to show variations in size, shape, and structure.

A—Series to illustrate variation in size from 6 mm. to 32 mm.

B—Series to illustrate variation in relative lengths of horizontal diameters resulting in variation in shape from spheroidal to ellipsoidal.

C—Series to illustrate variations in relative lengths of vertical and horizontal diameters resulting in different degrees of flattening.

D—Series to illustrate various stages of decortication resulting from weathering to show the relative durability of the outermost "skin" of the mud balls.

E—Series of polished sections illustrating concentric nature of mud balls and thickness of outer skin.

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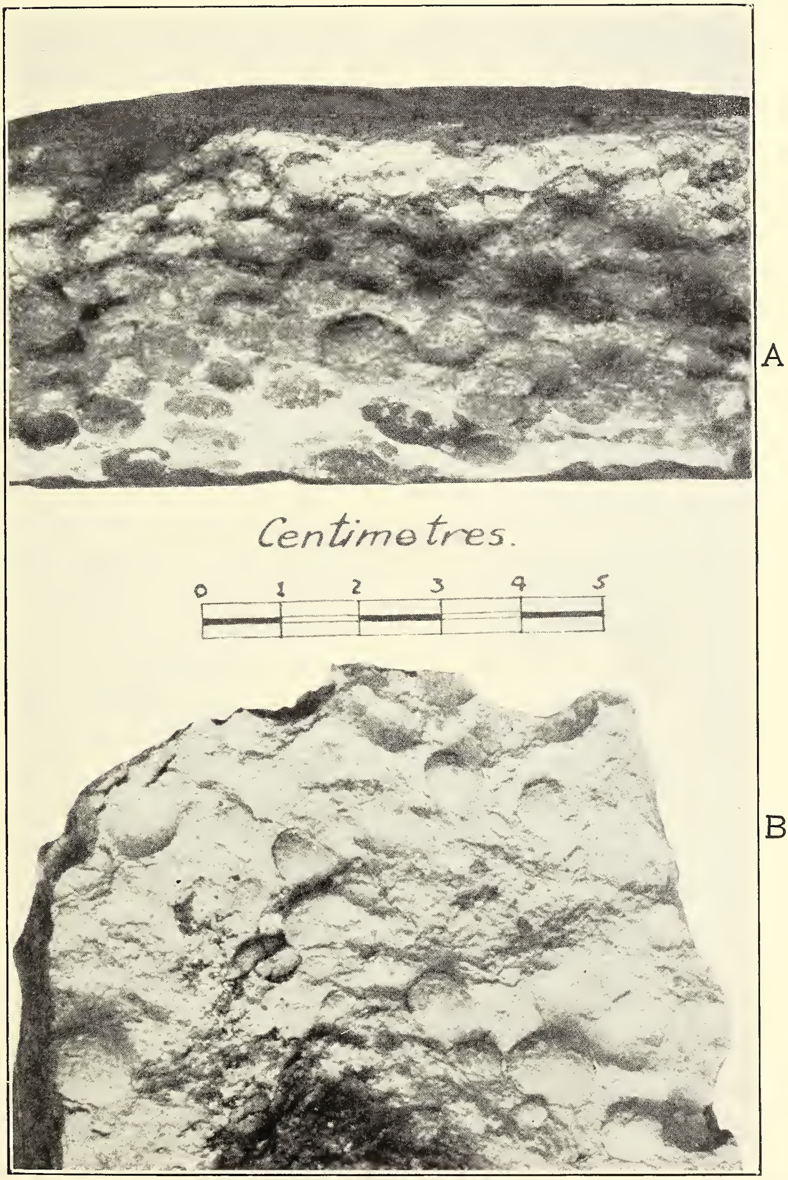
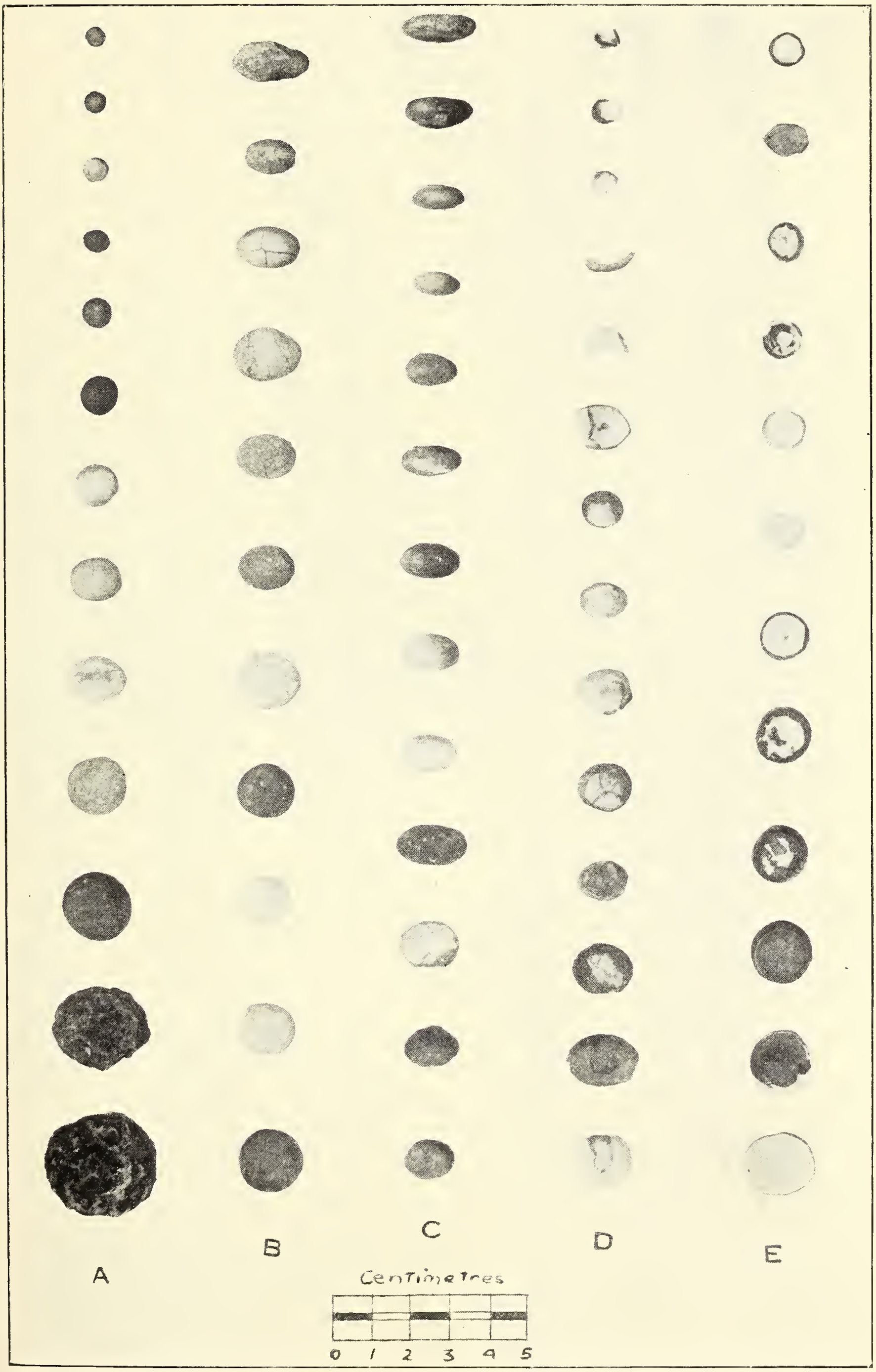
6. H. C. Richards, A.A.A.S. Vol. XVII., 1924, Volcanic Activity in Qld., p. 286.



Photographs of hand specimens of tuff, showing the arrangement of volcanic mud balls in their matrix.


A
B
C
D
E
Centimetres
0 1 2 3 4 5

Plants Collected in the Mandated Territory of New Guinea by C. E. Lane-Poole.

By C. T. White, Government Botanist, and W. D. Francis, Assistant Government Botanist, Brisbane.

Plates IV. and V.

(*Read before the Royal Society of Queensland, 26th September, 1927.*)

After reporting on the forests of Papua, Mr. C. E. Lane-Poole proceeded to the Mandated Territory of New Guinea and made an investigation of the forests of that territory on behalf of the Commonwealth Government. In the course of the work he collected a large number of botanical specimens during the latter part of 1923 and in 1924. This paper contains records of the plants collected during that period. As a forester, Mr. Lane-Poole paid particular attention to the trees. Comprehensive notes on the specimens he collected and an account of his investigation will be found in his report, "The Forest Resources of the Territories of Papua and New Guinea," which was published by the Commonwealth Government in 1925. Unfortunately, 125 botanical specimens were destroyed by the natives in an attack upon Mr. Lane-Poole's camp on the Ramu River. The plants collected in Papua (British New Guinea) by Mr. Lane-Poole are dealt with by us in these Proceedings, Vol. XXXVIII., p. 225–261, 1927.

Family GLEICHENIACEÆ.

Gleichenia dichotoma Hook. Nomi River, Finschhafen District, 549, sterile fronds, Novr., 1923.

Family TAXACEÆ.

Podocarpus cupressina R. Br. Ogeramnang, Finschhafen District, 554, foliage specimens, Novr., 1923.

Podocarpus amara Blume. Ogeramnang, Finschhafen District, 552, foliage specimens, Novr. 1923.

Dacrydium elatum Wall. (?). Joangey, Finschhafen District, 567, foliage specimens, Novr. 1923.

Phyllocladus hypophyllus Hook. f. Salawaket, 9,000 ft., 518, foliage specimens, Novr. 1923.

Family PINACEÆ.

Araucaria Cunninghamii Ait. Hanep, 639, foliage specimens, Feb., 1924.

Libocedrus papuana F. v. M. Salawaket, 520, foliage specimens, Novr., 1923.

Family GNETACEÆ.

Gnetum gnemon Linn. Kulungtufu, Finschhafen District, 563, flowering specimens (male and female), Novr., 1923. C. E. Lane-Poole remarks that it is prized for its leaves as a vegetable and is cultivated at all altitudes.

Family LILIACEÆ.

Dracæna angustifolia Roxb. Yonombo, 632, flowering specimens, Feb., 1924.

Family IRIDACEÆ.

Libertia pulchella Spreng. Salawaket, 8,000–10,000 ft., 507, flowering specimens, Novr., 1923.

Family FAGACEÆ.

Quercus lamponga Miq. Yunzain (Jungaing), Finschhafen District, 585, foliage specimens accompanied by old acorns, Decr., 1923.

Quercus spicata Smith var. *depressa* King. Yunzain, Finschhafen District, 582, fruiting specimens, Decr., 1923.

Family MORACEÆ.

Dammaropsis Kingiana Warbg. Nomi Valley, Finschhafen District, 550, fruiting specimens, Novr., 1923. The petiole in these specimens measures 5 cm. in length.

Family URTICACEÆ.

Laportea corallodesme Lautb. Yonombo, 633, flowering specimens.

Elatostemma macrophyllum Brongn. var. *majusculum* H. Winkl. Nomi River, 5,000 ft., Finschhafen District, 539, flowering specimens, Novr., 1923.

Elatostemma sesquifolium Hassk. Nomi River, 5,000 ft., Finschhafen District, 541, flowering specimens, 22nd Novr., 1923.

Cypholophus pachycarpus H. Winkl. Nomi River, 5,000 ft., 547, flowering specimens, Novr., 1923.

Family LORANTHACEÆ.

Loranthus Novæ-Guineæ F. M. Bailey. Malu (230 miles up the Middle Sepik River), 790, flowering specimens, July, 1924.

Family POLYGONACEÆ.

Muhlenbeckia platyclada Meissn. Ogeramnang, Finschhafen District, 551, flowering specimens, Novr., 1923. On tree stems.

Family HIMANTANDRACEÆ.

Himantandra Belgraveana Diels. Ogeramnang, Finschhafen District, 556, foliage specimens, Novr., 1923; 568, Joangey, Finschhafen District, immature flowering specimens, Decr., 1923.

Family LAURACEÆ.

Cinnamomum massoia Schewe var. *rotundatum* Schewe. Finschhafen, 592, foliage specimens, Dec., 1923.

Family SAXIFRAGACEÆ.

Kania eugenioides Schlechter. Ogeramnang, Finschhafen District, 558, flowering specimens, Novr., 1923.

Polyosma lagunensis Merrill. Likdin (Lavengai—New Hanover of Germans), 801, flowering specimens, Aug., 1924.

Family CUNONIACEÆ.

Weinmannia Ledermanii Schlechter. Likdin (Lavengai—New Hanover of Germans), 802, fruiting specimens, Aug., 1924. The specimens differ from those described by Schlecter, Engl. Bot. Jahrb. 52, 162 (1914), in the pubescent petiole and leaf rhachis. In this respect they approach *W. papuana* Schlecter.

Family ROSACEÆ.

Rubus Ferdinandi-Muelleri Focke. Salawaket, 10,000 ft., 511 and 512, flowering specimens, Novr., 1923. For the determination of these specimens we are indebted to Mr. V. S. Summerhayes, Royal Botanic Gardens, Kew.

Parinarium laurinum A. Gray. Mavelo River, 810, fruiting specimens, Septr., 1924. Lane-Poole states that the rind of the fruit is grated on the stem of a Pandanus and used as a caulking for canoes by the natives.

Family LEGUMINOSÆ.

Serianthes sp. Allied to *Serianthes grandiflora* Benth. The specimens differ from descriptions of *S. grandiflora* in having narrower (7 mm. wide), and more numerous (13–15 pairs) leaflets and in the greater distance (1·5 cm.) of the gland from the base of the petiole. Amage (Upper Ramu), 649, flowering specimens, March, 1924.

Afzelia bijuga A. Gray. Finschhafen, 588, foliage specimens, Decr., 1923.

Bauhinia Schlechteri Harms. Mogendo (Lower Sepik River), 793, foliage specimens accompanied by pods. Pod 25 cm. long and 9 cm. broad, containing 4 seeds. Seeds obliquely orbicular, 3–4 cm. in breadth, 6–10 mm. thick.

Pterocarpus indicus Willd. Finschhafen, 587, fruiting specimens, Decr., 1923.

Family RUTACEÆ.

Evodia accedens Blume sens. lat. Ramu, 630, flowering specimens, Feb., 1924.

Family MELIACEÆ.

Cedrela Toona Roxb. var. Yalu, 626, foliage specimens accompanied by dry capsules, Decr., 1923.

Family OXALIDACEÆ.

Averrhoa Bilimbi Linn. Malu (230 miles up Middle Sepik River), 789, fruiting specimens, July, 1924.

Family EUPHORBIACEÆ.

Breynia cernua Muell. Arg. Yalu, 611, fruiting specimens.

Baccaurea papuana F. M. Bailey. Yalu, 625, flowering specimens, Decr., 1923.

Bridelia subnuda K. Sch. et Lauterb. Mogendo (Lower Sepik River), 794, flowering specimens, July, 1924.

Homalanthus populifolius Grah. Joangey, Finschhafen District, 576, flowering and fruiting specimens, Decr., 1923.

Family ANACARDIACEÆ.

Spondias dulcis Forst. f. Mavelo, 809, flowering specimens, Septr., 1924.

Dracontomelum mangiferum Blume. Yalu, 613, fruiting specimens, Decr., 1923.

Campnosperma brevipetiolata Vlks. Marienburg, Lower Sepik River, 785, fruiting specimens, July, 1924; 799, Likdin (Lavengai—New Hanover of Germans), flowering specimens, Aug., 1924.

Family SAPINDACEÆ.

Pometia pinnata Forst. Finschhafen, 586, foliage specimens, Decr., 1923.

Dodonæa viscosa Linn. Ogeramnang, Finschhafen District, 561, fruiting specimens, Novr., 1923.

Family ELÆOCARPACEÆ.

Echinocarpus papuanus Schlechter. Yunzain (Jungaing), Finschhafen District, 583, specimens bearing flowers and accompanied by capsules, Decr., 1923. Capsule oval or elliptical, hard and woody, 5–6 cm. long, 3–4 celled, outer surface glabrous and unarmed in the old specimens at hand.

Anoniodes pulchra Schlechter. Joangey, Finschhafen District, 581, specimens accompanied by capsules, Decr., 1923. The capsules are ovoid or globose, hard and woody, 3–4 celled, 4–5 cm. long, densely pubescent on outside and armed with somewhat flexible, almost pungent processes attaining 1·8 cm. in length, the indumentum of the capsule extending along the processes but absent from their apices. The seeds are described by Lane-Poole as red with black tips.

Family MALVACEÆ.

Hibiscus D'Albertisii F. v. M. Abunti, 786, flowering specimens, July, 1924.

Fig. 1.—*Saurauja emarginata* sp. nov. Both natural size. Fig. 2.—*Eurya albiflora* sp. nov.

Face page 65.] [*Photos.: Dept. Agriculture and Stock.*

Family STERCULIACEÆ.

Pterocymbium stipitatum White and Francis. Yalu, 602, flowering specimens, Decr., 1923. This species is illustrated in the authors' paper in these Proceedings, XXXVIII., 242 (1927).

Family DILLENIACEÆ.

Saurauja emarginata sp. nov. (Plate IV., fig. 1.)

Arbor parva, partibus junioribus et ramulis et petiolis et pedunculis et foliis subtus lepidis triangularibus obtectis; foliis petiolatis, oblanceolatis serratis apice acutis et mucronulatis basem versus angustatis subtus pallidioribus nervis lateralibus 8–10 in utroque latere supra impressis subtus elevatis; floribus albis axillaribus singularibus, pedunculis in parte superiore bi-bracteatis, calyce alte 5-lobato, lobis ovatis obtusis intus ad basem pubescentibus; petalis emarginatis; antheris numerosis, linearibus loculis rima dehiscentibus, ovario globoso dense pubescenti, stylis 5 basem versus connatis.

Described by the collector as a small tree 4.5 m. high. Young shoots, branchlets, petioles, peduncles and underside of leaves furnished with a few triangular scales 1–1·5 mm. long. Branchlets terete, about 2 mm. in diameter 10 cm. below apex. Petioles 1–3 mm. long. Leaf blades oblanceolate, serrate, apex acute and mucronate, narrowed towards the base, under side paler than upper side, midrib and lateral nerves visible on both sides but more prominent on the under side, reticulate veins visible and impressed on upper side, 5–7 cm. long, 3–3½ times as long as broad. Flowers single in the axils, described by the collector as white, glabrous except for an occasional scale on the calyx, the densely pubescent ovary and pubescent inner side of the calyx lobes at their base. Peduncles 3 cm. long with two opposite ovate-lanceolate bracts 7 mm. long situated about 6 mm. below the flower. Calyx divided to the base; lobes ovate, obtuse, 8 mm. long, 3–4 mm. in breadth. Petals emarginate or notched at the apex, 13–15 mm. long, about 5 mm. in breadth. Anthers numerous, linear, 2·5–3 mm. long, attached at the back near the base, opening in longitudinal slits; filaments exceedingly short. Ovary globose, densely pubescent, 5–celled; styles 5, 5 mm. long, united towards base.

Locality: Edge of limestone precipice above Nomi River, 7,000 ft., 528, C. E. Lane-Poole, Novr., 1923.

Allied to *S. Roemeri* Lauterb., from which it differs in its smaller leaves, single-flowered inflorescence, and narrower bracts and calyx lobes.

Saurauja conferta Warbg. Nomi River, 5,000 ft., Finschhafen District, 538, flowering specimens, Novr., 1923. Differs from Warburg's description in having larger leaves (up to 30 × 11 cm.), longer peduncles (up to 5·5 cm.), and longer styles (up to 1 cm.).

Family TERNSTRŒMIACEÆ.

Eurya albiflora sp. nov. (Plate IV., fig 2.)

Frutex vel arbor parva, ramulis et foliis subtus pilis longis sericeis fuscis dense vestitis, foliis distichis petiolatis cordatis vel ovatis coriaceis apice emarginatis margine serrulatis subrecurvis costa media et venis supra alte impressis floribus alvis glabris pedicellatis axillaribus singularibus vel 2–3 fasciculatis, pedicellis puberulis; bracteis 2 ovatis obtusis; sepalis imbricatis concavis orbicularibus; petalis obovatis ad basem brevissime connatis; staminibus 5, filamentis complanatis, antheris ovatis ad basem cordatis; ovario ovoideo.

Described by collector as a shrub or small tree about 6 m. high. Branchlets and underside of leaves densely pubescent with long, brown hairs. Branchlets about 2 mm. in diameter 10 cm. from apex. Branchlets slightly flexuose. Leaves distichous. Petioles about 1 mm. long. Leaf blades cordate or ovate, apex finely emarginate, margins finely serrate, somewhat recurved, texture thick, midrib, lateral nerves and a few reticulations prominent and impressed on the upper surface, venation obscured by the long hairs on the under side, 13–17 mm. long, 9–10 mm. wide. Flowers white (C. E. Lane-Poole), glabrous, axillary, mostly single, or in clusters of 2 or 3. Pedicels puberulous up to 2 mm. long. Bracts subtending flowers 2, ovate, obtuse, 2 mm. long. Sepals strongly imbricate, concave, orbicular, attaining 3 mm. in breadth. Petals obovate, very shortly united at base, 3 mm. long. Stamens 5, alternating with petals, about 3 mm. long; filaments flattened, 2 mm. long; anthers ovate, cordate at base, about 2 mm. long. Ovary ovoid, 1·5 mm. long.

Sarawaket, 10,000 ft., 505, C. E. Lane-Poole. Novr., 1923.

In appearance the new species approaches the Philippine *Eurya buxifolia* Merrill, from which it is readily distinguished by its smaller, obtuse leaves and densely pubescent branchlets and underside of leaves.

Family OCHNACEÆ.

Schuurmansia Henningsii K. Sch. Joangey, Finschhafen District, 580, flowering specimens, Decr., 1923.

Family THEACEÆ.

Gordonia fragrans Merrill. Likdin (Lavengai—New Hanover of Germans), 804, flowering and fruiting specimens, August, 1924. The specimens differ from Merrill's description (Philipp. Jour. Science, 1, suppl. 1, 95–96, 1906) in having shorter petals (1·5 cm. long) and shorter fruit (2 cm. long).

Family FLACOURTIACEÆ.

Pangium edule Reinw. Wide Bay, 811, fruiting specimens, Septr., 1924. Lane-Poole remarks that the kernel of the nut is eaten by the natives after washing to remove toxic principle (hydrocyanic acid).

Fig. 1.—*Mearnsia cordata* sp. nov. Both natural size. Fig. 2.—*Hoya Poolei* sp. nov.

Face page 67.] [*Photos.: Dept. Agriculture and Stock.*

Homalium pachyphyllum Gilg. Korindal, 798, flowering specimens, Aug., 1924.

Family DATISCACEÆ.

Octomeles sumatrana Miq. Yalu, 589, fruiting specimens, Decr., 1923.

Family LECYTHIDACEÆ.

Barringtonia quadrigibbosa Lauterb. Likdin (Lavengai—New Hanover of Germans), 803, flowering specimens, Aug., 1924. In the absence of the fruit the determination is somewhat doubtful. The racemes in the specimens attain 70 cm. in length.

Planchonia timorensis Blume. Yalu, 606.

Family MYRTACEÆ.

Mearnsia cordata sp. nov. (Plate V., fig. 1.)

Arbor parva partibus junioribus tomentosis; foliis brevissime petiolatis cordatis apice obtusis acuminatis vel rarius rotundatis margine recurvis nervis lateralibus in utroque latere 12 venis et venulis et supra et subtus visibilibus sed subtus multo prominentioribus; floribus glabris parte inferiore defoliata ramulorum ortis, in fasciculis umbellis vel racemis brevis dispositis; calycis lobis 4 latis obtusis; petalis 4, orbicularibus, staminibus 15–20, filamentis filiformis, antheris avatis; ovario 2-loculari (?), stylo tenuo.

Described by collector as a small tree up to 9 m. high. Young branches tomentose, very young leaves pubescent. Branchlets 2·5 mm. in diameter 18 cm. from apex, the older parts covered by a loose, brown baık. Petioles very short and broad, 1–2 mm. long. Leaf blades cordate, acuminate or occasionally round at apex, margins recurved, midrib, about 12 lateral nerves on each side of midrib and numerous reticulate veins visible on both surfaces but raised and prominent on the underside, 3–5 cm. long; the broad leaves are nearly as broad as long, the narrow ones about twice as long as broad. Flowers glabrous, in clusters, umbels or short racemes on the branches below the leaves. Pedicels 3–6 mm. long. Calyx campanulate, about 4 mm. long, the upper free part of the tube spreading and about 1·5 mm. long, lobes 4, broad, obtuse. Petals 4, orbicular, about 2 mm. in diameter. Stamens 15–20; filaments filiform, red (C. E. Lane-Poole), attaining 11 mm. in length; anthers ovate, basifixed, about ·5 mm. long. Ovary apparently 2-celled; style slender, 12 mm. long.

Limestone precipice above Nomi River, 534, C. E. Lane-Poole, Novr., 1923.

This species is allied to *Mearnsia ramiflora* Diels. from which it differs in its cordate leaves.

Eucalyptus Naudiniana F. v. Mueller. Korindal, 797, flowering specimens, 1st Aug., 1924.

Family MELASTOMACEÆ.

Osbeckia chinensis Linn. Grass hills, upper Ramu up to 1,700 ft., 638, flowering specimens, 29th Feb., 1924.

Family UMBELLIFERÆ.

Œnanthe Schlechteri Wolff. Nomi River, 5,000 ft., Finschhafen District, 542, flowering specimens, Novr., 1923.

Family ERICACEÆ.

Rhododendron Commonæ Forster. Salawaket, 6,000–9,000 ft., 502, flowering specimens, 20th Novr., 1923.

Rhododendron Carringtoniæ F. v. M. Divide between Nomi and Ake, Salawaket, 7,000 ft., flowering specimens, Novr., 1923. The flowers are longer (8·5 cm.) and the corolla tube narrower (less than 4 mm. in diameter) than described by Mueller. The stamens are exserted. Lane-Poole remarks that the flowers are white and fragrant.

Rhododendron Hansemanni Warbg. Edge of limestone precipice above Nomi River, 7,000 ft., Finschhafen District, 531, flowering specimens, Novr., 1923.

Rhododendron warianum Schlechter. Edge of limestone precipice above Nomi River, 7,000 ft., Finschhafen District, 532, flowering specimens, Novr., 1923.

Diplycosia mundula Schltr. Salawaket, 6,000–12,000 ft., 504, flowering specimens, 20th Novr., 1923.

Agapetes Moorhousiana F. v. M. Joangey, Finschhafen District, 575, flowering specimens, Decr., 1923. Lane-Poole describes the flowers as rose-coloured.

Family SAPOTACEÆ.

Chrysophyllum Roxburghii G. Don. Yalu, 614, fruiting specimens, Decr., 1923.

Family LOGANIACEÆ.

Fagræa obovata Wall. Edge of limestone precipice above Nomi River, Finschhafen District, 533, flowering specimens, Novr., 1923.

Family GENTIANACEÆ.

Exacum tetragonum Roxb. Grass hills of upper Ramu up to 1,700 ft., 636, flowering specimens, Feb., 1924.

Family APOCYNACEÆ.

Alstonia macrophylla Wall. Joangey, Finschhafen District, 571, flowering specimens, Decr., 1923.

Alstonia scholaris R. Br. Yalu, 594, foliage specimens.

Family ASCLEPIADACEÆ.

Hoya Poolei sp. nov. (Plate V., fig. 2.)

Planta scandens glabra; foliis petiolatis textura carnosis (in sicco coriaceis) lanceolatis vel ellipticis apice acuminatis; pedunculis axillaribus, umbellis 6–8 floris, pedicellis tenuissimis calycis lobis lanceolatis, corollæ lobis deltoideis, coronæ foliolis horizontalibus anguste ovoideis supra concavis.

Described by collector as a Hoya-like creeper. Glabrous. Petioles 4–6 mm. long. Leaf blades fleshy, lanceolate or elliptical, acuminate, venation indistinct in dried specimens, 6–9 cm. long, about thrice as long as broad. Peduncles axillary, 2–3 cm. long, bearing an umbel of 4–8 flowers. Pedicels very slender, 8–17 mm. long. Flowers glabrous, described by collector as white with pink centres. Calyx about 4 mm. in diameter; lobes lanceolate, about 1 mm. long. Corolla about 1·2 cm. in diameter, lobes deltoid about 3 mm. long. Corona scales horizontal and spreading to about 2·5 mm., narrowly ovoid, concave above, posterior obtuse.

Locality: Joangey, South-Eastern end of Finisterre Range, 566, C. E. Lane-Poole, Decr., 1923.

Allied to *Hoya gracilipes* Schlechter (Nachtrage, Fl. deutsch. Schutzgeb. Sudsee, 363, 1905) from which it differs in its shorter peduncles and glabrous corolla.

Family CONVOLVULACEÆ.

Ipomœa Batatas Poir. Sweet Potato. Kulungtufu, Finschhafen District, 564, flowering specimens, Novr., 1923. Common in old garden lands.

Family BORAGINACEÆ.

Cordia Myxa Linn. Lea, 628, flowering specimens, Jan., 1924.

Zoellera procumbens Warbg. Salawaket, 8,000–12,000 ft., 506, flowering specimens, Novr., 1923.

Family VERBENACEÆ.

Vitex Cofassus Reinw. Yalu, 590, flowering specimens, Decr., 1923.

Family SOLANACEÆ.

Solanum aviculare Forst. Nomi River, Finschhafen District, 544, flowering and fruiting specimens, Novr., 1923.

Family GESNERACEÆ.

Bœa lanuginosa Lauterb. et Schum. Hanep, 640, flowering specimens, Feb., 1924.

Dichrotrichum Chalmersii F. v. M. Joangey, Finschhafen District, 572, flowering specimens, Decr., 1923. Lane-Poole describes the flowers as wine-coloured.

Family ACANTHACEÆ.

Calycacanthus Magnusianus K. Schum. Rain forest on hills of upper Ramu to 3,000 ft., 637, flowering specimens, 29th Feb., 1924.

Family RUBIACEÆ.

Mitragyna parvifolia Korth. Awatib, 792, fruiting specimens, July, 1924.

Mussænda frondosa Linn. var. *glabriflora* K. Sch. Joangey, Finschhafen District, 565, flowering specimens, Decr., 1923.

Family COMPOSITÆ.

Olearia vernonioides White and Francis. Salawaket, edge of Libocedrus forest and grass lands, 509, flowering specimens, Nov., 1923.

Blumea chinensis DC. Joangey, Finschhafen District, flowering specimens, Decr., 1923.

Emilia prenanthoidea DC. Edge of limestone precipice above Nomi River, Finschhafen District, 537, flowering specimens, Novr., 1923.

A Survey of the Brisbane Schists.

By A. K. DENMEAD, B.Sc. (Research Student, University of Queensland).

Plates VI.-X., and Text-figures.

(Read before the Royal Society of Queensland, 26th September, 1927.)

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I.—INTRODUCTION.

Investigations, the results of which form the substance of the present paper, were begun in connection with the field work prescribed as part of the Fourth Year Course at the University of Queensland. The objects of the work were:—

(i.) To determine the sequence of the beds.
(ii.) To determine the main structural features of the series.
(iii.) To attempt to correlate several widely separated occurrences.
(iv.) To determine the age of the series.

The writer does not claim in the limited time at his disposal to have made any but a very general survey of the Brisbane Schists; many of his conclusions are tentative, and some of the problems have so far defied solution. He will feel amply repaid for his labours if he has indicated lines of research for future workers on one of the most interesting and complex series in Eastern Australia.

There are abundant references to the Brisbane Schists in Australian geological literature, but they are for the most part incidental, or deal with local occurrences; little has been done until very recently in the way of correlation. Most of the references will be cited in the text. One reference only will be mentioned here, which, although now of little value, has an historical interest, for it contains the earliest account of the Brisbane Schists. This is Leichhardt's "Beitrage Zur Geologie von Australien," published in 1855. My attention was drawn to this work by Dr. F. W. Whitehouse, to whom I am indebted for a translation of parts of the paper.

II.—Distribution of the Brisbane Schists.

According to the official view of the Geological Survey (*see* Appendix to Harrap's "Geography of Queensland"), the Brisbane Schist series extends north-westerly from Coolangatta to Nanango through Southport, Nerang, Beenleigh, Brisbane, Enoggera Range, Taylor Range, D'Aguilar Range, Mt. Crosby, and Kilcoy. Equivalent series are (1) the Amamoor series developed at Black Snake, Marodian, Amamoor, Kandanga, and Mt. Walli; and (2) the Gladstone–Curtis Island series outcropping at Cawarral, Yeppoon, Emu Park, the islands of Keppel Bay, Curtis Island, Facing Island, Gladstone, and Mt. Millar. There is no doubt that the metamorphic series in the extreme north-east of New South Wales is a continuation of the Brisbane Schist series; and Dr. W. H. Bryan [1] believes the Coff's Harbour Schists also to be equivalents. Lately Mr. C. H. Massey has proved the presence of the Schists on many of the islands of Moreton Bay. They occupy the whole of the east coast of Macleay Island, and are also well developed on Russell, Stradbroke, and other islands. It is generally believed that the "schists" occurring to the south and east of Gympie, including the Kin Kin phyllites of Jensen [2], belong to the Brisbane Schists.

III.—Physiography.

In general the Brisbane Schists are hard, weather-resisting rocks, and this characteristic is reflected in the topography of the country where they outcrop. The coastal strip between Tweed Heads and Brisbane, except where it has been levelled by wave erosion, is very hilly, although not of great altitude, the highest mountains scarcely rising above 800 ft. The hilly strip goes inland north from Brisbane. This is due to the covering of the Schists on the coastal area by lacustrine deposits of Triassic and Tertiary age. In the extreme south-east of Queensland the Mesozoic and Tertiary sediments are unaffected by severe earth-movements, and in general their outcrops are characterised by flat or undulating country. An exception to this rule is found in the Bundamba Sandstone series, whose outcrops occasionally resemble those of the Hawkesbury Sandstones in forming sharp ridges with precipitous sides. Escarpments of this nature are to be seen within a few miles of Brisbane, and at a distance are apt to deceive one into imagining them to be composed of the old metamorphic rocks.

An examination of a feature map of the Moreton district shows a striking N.N.W. and S.S.E. trend, not only of mountains, but also of river valleys which run parallel with the mountain chains for long distances, and then, turning sharply, pursue a zig-zag course to the sea.

There is a definite parallelism between geological structures and topographical features. The trend of the Schists is N.N.W. and S.S.E., and we find quartzite ridges frequently following these trends. It has been found that where topographic features cut across the trend they are generally associated with faulting movements. Examples are the North Pine River, the Brisbane River, and probably also the Logan River.

As a rule Schist country is hilly, and often on this account inaccessible.

Inliers of Schist in the Ipswich series of Mesozoic age are by no means uncommon. In general they form more or less rugged hills surrounded by the flat or undulating country occupied by the younger rocks. On this account E. O. Marks [3] concluded that the floor on which the Mesozoic sediments were deposited was very uneven.

In general the Schist produces a poor soil that supports meagre forests of ironbark and other eucalypts. Certain basic rocks, however, that are associated with quartzites produce a deep red soil that has been found very rich for cultivation purposes. Examples of such country are seen at Mt. Cotton, at Kenmore and Brookfield, west of Dayboro', at Belmont, and in many other localities. The basic rocks of Mt. Mee, Dayboro', &c., produce soils of only medium quality.

IV.—Petrological Types within the Brisbane Schists.

The rocks described as "Schists" present a great variety of types, including the following:—Mudstones, fine-grained shales, micaceous shales, sandstones, quartzites, cherts, grits, boulder beds, greywackes, banded slates, jaspers, calcareous grits, altered tuffs, serpentines, andesite tuffs, phyllites, quartz-mica schists, granulites, amphibolites, altered porphyrites, chiastolite schists, actinolite schists, glaucophane schists, and many other metamorphic rocks.

Excepting in the neighbourhood of granitic intrusions there are no true schists in the entire Brisbane Schist series. Although the term has been retained in the present paper, the author would stress the fact that it cannot be regarded as in any sense descriptive.

In spite of the great variety of rock types included in the Brisbane Schists, Mr. B. Dunstan, Chief Government Geologist of Queensland, recognised three belts, each characterised by certain rock types (*see* p. 101).

The author has recognised four broad divisions in the Brisbane district, as follows:—

(1) The Greenstone series, consisting almost entirely of altered basic rocks.

(2) The Bunya series, consisting chiefly of mica phyllites.

(3) The Neranleigh series, a name given by Mr. C. C. Morton of the Queensland Geological Survey for the series of greywackes, slates, &c., occurring between Nerang and Beenleigh. First noted by W. H. Rands [4].

(4) The Fernvale series, comprising ferruginous jaspers, banded cherts, slates, limestones, &c., with intrusive serpentine, named after the locality from which they were described, by Richards and Bryan [5].

V.—The Greenstone Series.

The rocks included under this heading are the least known and at the same time the most interesting rocks of the series. They are apparently enormously thick, and underlie the mica-phyllites. The term "greenstone" includes all those altered basic rocks described by Jensen [6] from Mt. Mee and other places, as well as the rocks that are described here.

Greenstone is seen outcropping on the Mt. Mee road not far from the Dayboro' railway station. Half a mile from Dayboro', mica-schist occurs striking north-north-west and dipping at a high angle in a westerly direction. The junction between the greenstone and the mica-schists is obscured by a great thickness of soil.

At Petrie the greenstone strikes east and west and dips vertically. One mile along the Dayboro' road there occur interbedded (?) mica-phyllites that are very much contorted and penetrated by veins of a pegmatitic nature, with quartz and felspar in intimate intergrowth. Such rocks are traversed for about one-third of a mile, when greenstone is again met with, striking north-north-west and south-south-east.

Greenstone occurs continuously from this point to within one mile of Dayboro'. The strike over this section departs little from the normal direction, and the dips (of the foliation planes), where observed, are easterly and rather steep. The rock is in general quite massive, but may become highly schistose. The schistosity is more pronounced in the western half of the section.

In the hand specimen, the greenstone exhibits a good deal of variation. Four main textural types have been recognised—

(1) Porphyritic massive greenstone;

(2) Fine-grained greenstone, usually massive, occasionally somewhat sheared;

(3) Porphyroblastic schistose greenstone;

(4) Foliated felspathic greenstone.

(1) *Porphyritic Massive Greenstone.*—A grass-green, very tough rock, with phenocrysts of a decomposed, often greenish mineral. In some specimens partly decomposed felspar can be recognised. The phenocrysts have in some cases been completely removed by weathering or solution, leaving impressions the shape of which indicates the idiomorphic nature of many of the original phenocrysts. The green mineral which appears to have replaced the felspar phenocrysts is very soft and is of a chloritic nature. Hornblende needles have been noticed in some specimens.

Under the microscope the rock exhibits a typical porphyritic structure. The phenocrysts frequently have an extremely ragged outline, and are in some cases almost completely replaced by sericite, chlorite, and epidote. The less-altered phenocrysts are twinned, usually on the albite type, but occasionally on the Carlsbad type, and are mostly plagioclase with some orthoclase. The groundmass consists of epidote in small grains, flakes and fibres of chlorite and talc. Hornblende is present, though sparingly, in small grains in some sections. In the greenstone from Stradbroke Island the phenocrysts, which are more completely replaced than those in the Petrie rock, are generally idiomorphic to sub-idiomorphic in outline. Pyrites is present in notable quantity. (*See* Plate VI., fig. 1.)

Although very altered, this type of greenstone cannot have been buried to the lowest zone of schist formation, for the minerals present are all products of katamorphism. It follows, too, that it must have been remote from major igneous intrusions.

(2) *The Fine-grained Greenstone* often differs markedly from the porphyritic type in mineralogical as well as textural characters. It is usually dark green in colour and very tough. It is composed of glistening crystals of hornblende and actinolite (?). Under the microscope a definite banded arrangement is seen. There is a chloritic groundmass which is very fine-grained with parallel strings of iron ore and well cleaved sections of hornblende, which is green and strongly pleochroic. Actinolite, colourless or very pale green, occurs in elongated flakes with good cleavage parallel to the longer axis. Radiating aggregates of epidote are occasionally seen. Chlorite, pale green with very ragged edges, occurs in grains up to 0·5 mm. in diameter. Some secondary quartz is present. The rock appears to have been completely recrystallised and every trace of original texture is obliterated. (*See* Plate VI., fig. 2.)

The minerals present in this type of greenstone indicate that the rock has been affected by some igneous intrusion or has been deeply buried. The former is more probably the case, for such a rock has been found within a short distance of the porphyritic massive type. If any phenocrysts were originally present they have been completely replaced and all indications of their presence destroyed.

(3) *Porphyroblastic Schistose Greenstone.*—The porphyroblasts are similar to the phenocrysts in the massive rock. They give evidence of their primary origin in that the other minerals are folded about them, giving a knotted appearance in the hand-specimen (''Knotenscheifer''). Talcose minerals are abundant. Chlorite is also present in dark-green scales.

This type, which occurs at Kilcoy, has undergone great shearing strain, but it has been encompassed only in the upper zone of Schist formation as is indicated by the nature of the minerals.

(4) *Felspathic Foliated Type.*—One other type of greenstone is to be described, namely, the felspathic foliated type.

This rock is found about two miles east of the Dayboro' railway, between Kobble and Armstrong Creeks. At this point the greenstone is interlaminated with bands of coarse-grained gneiss that obviously result from contact metamorphism by a hidden granitic mass, probably a northward extension of the Mt. Samson granite batholith, which forms the southern boundary of the greenstone in this area. These rocks are very decomposed, and no specimens of sufficient freshness were obtained for the making of thin sections. The recognisable minerals are tabular orthoclase, hornblende, muscovite, and probably other micas.

Here was found also a rock that may be described as ferruginous chiastolite-mica schist. This is a beautiful pink rock with a satiny lustre that consists of iron-stained mica with small black crystals of chiastolite. In thin section the mica is nearly opaque, showing a very definite schistose structure. Sections of chiastolite have their centres clouded with dust-like inclusions, while the outside rim is clear and colourless.

The greenstone is much more resistant to weathering agencies than the interlaminated gneiss. Fresh samples are to be obtained from outcrops that have been long exposed to the weather. The banded appearance of the greenstone is due to the segregation of the dark minerals. The rock is severely contorted and puckered, and has large pockets of white felspar occurring plentifully in it, producing a typical ''augen'' structure. The minerals recognisable in the hand specimen are felspar, small white grains with a somewhat vitreous lustre on the cleavage faces; actinolite, dark green. On a weathered surface the felspar stands out and considerably accentuates the banded appearance.

Under the microscope, turbid orthoclase occasionally twinned on the Carlsbad type is abundant. Numerous lath-shaped grains of fibrous, pale-green actinolite occur in parallel arrangement. Irregular grains of chlorite are present. The edges of the felspars are, in general, irregular, and they contain numerous inclusions of actinolite. In some cases they appear to have replaced the actinolite, but often the fibres of that mineral are folded about the felspar grains, whose peripheries are then more sharply defined. On the whole it appears that the felspars are secondary, some having developed during the disturbance that produced the foliation, and others after the schistosity was completed. The rock has undoubtedly resulted from the contact metamorphism of normal greenstone.

This felspathic type of greenstone can be observed to grade into the normal schistose variety as one proceeds east. Rocks similar to those described have been collected from Mt. Mee by Dr. W. H. Bryan.

Schistose greenstone with ''augen'' of felspar similar to that occurring near Dayboro' is encountered one mile east of Kilcoy. Near Kilcoy it is interbedded with mica phyllite.

North from here, greenstone outcrops in the bed of Sheep Station Creek. The strike there, as elsewhere in Kilcoy, is east and west. The greenstone here is many miles out of its line of strike, and has doubtless been brought to the surface by a heavy east-west fault. Greenstone fragments are abundant as inclusions in the granite to the east of Kilcoy.

Between Wamuran and Bracalba, on the Kilcoy railway, there occur clay slates, mica phyllites, and fine-grained granulites which overlie and are, to a certain extent, interbedded with more or less metamorphosed greenstone. The general strike direction is N.N.W. and S.S.E., and the dip is to the east at varying angles. The strike is frequently disturbed by faults which appear to strike in an east-west direction. Decomposed dykes penetrate the schists, and are probably responsible for the highly metamorphosed state of some of the rocks.

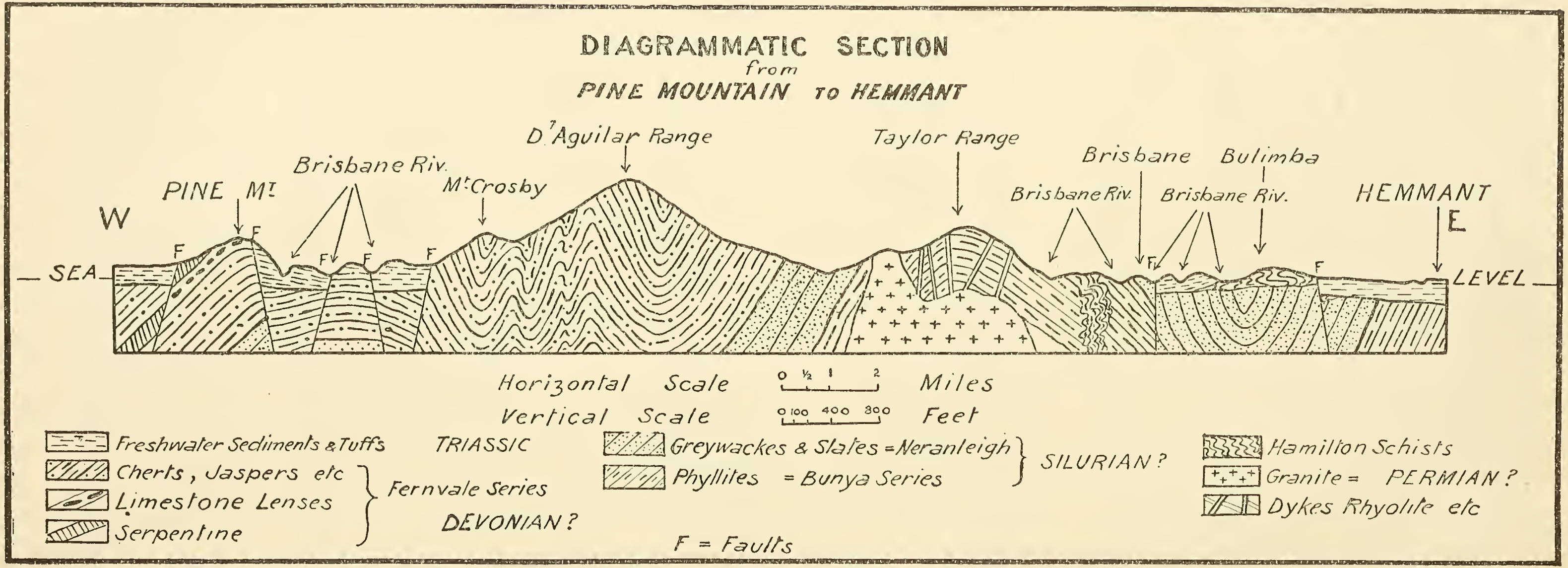
The Schist is separated from the Woodford granite by Bundamba sandstone, which is faulted against the granite between Bracalba and D'Aguilar.

Origin of the Greenstones.—The existence of only slightly altered felspar phenocrysts in the upper portion of the greenstone is of great importance, for there is every reason to believe that there the mineral is of primary origin. The abundance of ferro-magnesian constituents everywhere supports the evidence of the primary felspar in pointing to an igneous origin, and the general absence of quartz combined with the other features show that the original rock was basic in character. It appears highly probable that the porphyritic texture so common in the greenstone is really a primary texture, and so the portions of the series characterised by this texture may be looked upon tentatively as altered porphyritic andesite or porphyrite. The presence of elongated vesicles in the greenstone near Petrie suggests a flow rather than an intrusion.

In the section near Kilcoy, already mentioned, we have alternating greenstones and mica phyllites, and there can be little doubt that they are actually interbedded. If this is so, we are dealing either with (1) intrusions in the form of sills or (2), more probably, contemporaneous lava flows. When the prolonged period of violent volcanic activity was drawing to a close and the extrusions were becoming weak and intermittent, there would be deposited normal sediments in the periods of quiescence which would give place to lava for a short time, until finally the activity ceased altogether. All the evidence so far gathered tends to support the theory that the greenstones represent an altered series of basic lavas and possibly tuffs erupted partly at least under sub-aqueous conditions.*

Thickness of the Greenstones.—The maximum thickness of the series cannot be calculated, for the base is unknown. The Petrie-Dayboro' section, however, enables one to gain some idea as to the minimum

* H. I. Jensen (Proc. Linn. Soc. N.S.W., 1906, Part I.) believed that the altered basic rocks of Mount Mee, etc., were lava flows, the glaucophane schists representing the ancient volcanic necks.



Text-figure 1.

The Greenstone Series does not occur in this section. Elsewhere it underlies conformably the Bunya Series.

thickness which may be attributed to these rocks. Over a considerable distance of this traverse the greenstone is massive, there being no dip planes to indicate how the rocks may be disposed. Since all observed dips are easterly, it is reasonable to assume the direction of dip to be uniform throughout. The starting point will be the position where a N.N.W. strike is first observed about $1\frac{1}{2}$ miles from Petrie and the finishing point half a mile east of the Dayboro' granite. Assuming an average dip of 60 degrees we have a thickness of approximately 32,000 feet. This figure must be considered a conservative one, for a very generous allowance has been made for the displacing effect of the Dayboro' granite and the observed dips were rarely less than 60 degrees. When more is known of the greenstones north of Dayboro', the thickness may prove to be considerably greater. At all events there is ample evidence of violent vulcanicity extending over an enormous period in what we may term early Brisbane Schist times.

Summary of Section V.

The greenstones occur between Woodford and Armstrong Creek. They are cut off on the south by mica phyllites and on the north by granites. There is a small outcrop on Stradbroke Island. By contact metamorphism the greenstones are altered locally into hornblende-actinolite schists, glaucophane schists, etc. The normal greenstone consists of chlorite, talc, epidote, felspar (more or less altered), and sometimes quartz. Estimated thickness, 32,000 feet.

VI.—The Bunya Series: The Mica Phyllites.

In the heart of the city of Brisbane there is developed a rock that may be termed a mica phyllite. The rock often cleaves readily along the bedding planes, but in the more metamorphosed specimens the cleavage makes a large angle with the bedding. The present paper would be incomplete without an adequate description of the Brisbane Schist in the type locality, and since such a description has been given by Prof. H. C. Richards [7] it is quoted here in full:—

"(*a*) *In the Hand Specimen.*

"When fresh the schist is a dark-blue or grey rock which exhibits a plication usually well developed owing to its fine-grained nature. There is often evidence of much movement in the rock, as slickensided or grooved and polished surfaces are common.

"Fine veins of quartz are abundant, and they vary from the finest films to several inches in width. These quartz veins seem to be of two types—those which follow the plication or schistose plane of the rock and those which traverse it. The former are the more abundant.

"From the dark nature of the rock one would expect it to contain graphitic material, and microscopic investigation bears this out.

"Pyrites is abundant in the form of small specks, which usually occur in the thin quartz veins.

"On weathering, the rocks take on a rusty-brown appearance so familiar in any of the cuttings about the city. The softer micaceous minerals become chemically and mechanically eroded out, leaving the more resistant quartz veins usually stained brown by limonite. In the fresh rock, the iron is present in the ferrous condition, and the blue-grey colour of the unaltered schist is due to the ferrous iron, but, on weathering, the iron is present in the ferric state which gives the brown iron-stained appearance.

"(*b*) *Under the Microscope.*

"Under the microscope the schist shows very clearly its plicated character and also its fine-grained nature. The minerals present are quartz grains and flakes of mica. Quartz grains occur as an integral part of the original sedimentary rock, but there has been much quartz in the form of veins added by the deposition of silica from the filtrating solutions. The mica flakes are difficult to determine owing to their minuteness, but they do not appear to be chlorite for the most part. Chlorite—a greenish mica—does occur through the schists, but usually in veins with quartz. The micaceous flakes have been arranged with their longest axes parallel to the schistose plane of the rocks, and they are seen wrapped around the more-or-less-angular quartz grains. Through the rock there is much graphitic material arranged in layers, parallel also to the plication. Some of the zones appear to contain more than others. Most of the quartz veins appear to have been the result of a metasomatic replacement of the micaceous minerals by quartz, and occasionally calcite. The graphitic material is often not replaced, and lines of it passing through the quartz grains occur just as it does in the unreplaced schistose material. There are other veins, however, made up of quartz and calcite, which appear to have filled up cracks in the rock. These cut across the schistose planes, as a rule.

"Pyrites is very common, and is usually present as small granules through the quartz veins.

"From the nature of the rock, as observed in the hand specimen and under the microscope, one would expect it to weather into quartz grains, chlorite scales, and kaolin."

A chemical analysis is given by Prof. Richards and is quoted here (A), together with the average shale (B) and the average phyllite (C), both after Daly [8]. The analysis (A) was made by Mr. G. R. Patten, of the Department of Agriculture and Stock. The sample was taken from an excavation at the corner of Edward and Adelaide streets, Brisbane.

—	A.	B.	C.
SiO_2	61·62	58·38	57·1
Al_2O_3	21·20	15·47	20·6
Fe_2O_3	1·51	4·03	5·5
FeO	1·93	2·46	4·6
MgO	1·77	2·45	1·9
CaO	1·59	3·12	0·6
Na_2O	3·39	1·31	1·6
K_2O	3·07	3·25	3·7
H_2O	3·29	5·02	3·2
H_2O	0·03		
CO_2	n.d.	2·64	..
TiO_2	0·82	0·65	1·0
P_2O_5	0·17	0·17	..
MnO	0·07	Tr.	0·1
Total	100·56	100·41	100·0

It will be noticed that in chemical composition the Brisbane rock lies closer to the average phyllite than to the average shale. The chief points of difference between it and both shale and phyllite are the small quantities of iron oxides and relative abundance of soda. This last point is worthy of special notice, for it is in the proportions of soda that igneous rocks differ essentially from those of sedimentary origin, the soda being dissolved more readily than the potash. The abundance of alumina and excess of magnesia over lime, however, as was pointed out by Prof. Richards, clearly indicate the sedimentary character of the rock.

In the classification of U. Grubenmann [9] for the metamorphic rocks, the Brisbane phyllite lies within the "alkali felspar gneiss" group. This classification, however, has very little meaning as applied to the Brisbane phyllites, on account of the slight degree of metamorphism to which the series has been subjected.

Such a rock as has been described is the least crystalline of the Bunya series. As one proceeds from the metropolis westward a change in the character of the rocks is to be observed. The rocks are fairly uniform as far as the road-bridge over the Ipswich railway between Roma Street and Milton stations. Here the Schists become intensely foliated and contorted. The bedding planes and cleavage planes can only be traced by the quartz veins which are inclined to stand out somewhat, and which here and there make fantastic patterns on the face of the rock. Evidently, this is a zone of severe crushing, for less disturbed rocks occur to both east and west. Rocks of a similar character are to be observed in South Brisbane and West End. Mica schists are visible at Taringa, where the dip is noticeably less, becoming increasingly shallower until at Indooroopilly the rocks are horizontal and are penetrated by numerous dykes, both rhyolitic and porphyritic in character, and believed by W. H. Bryan [10] to be genetically related to the Enoggera granitic intrusion. The Schists have been rendered highly foliated, and their mineralogical composition and texture have been affected in places to a profound degree by the granite and associated dykes.

The area affected by the Enoggera intrusion is very large compared with the extent of the granite. This is partly due to the network of minor intrusives that penetrate the surrounding schists, but even where dykes do not appear at the surface, metamorphism is often intense.

The area to the north-west of Brisbane is much affected by intrusions of a granitic nature. North-west of the Enoggera intrusion we have the Camp Mountain granite, and continuing along the same line the Mt. Samson granite and then the Dayboro' intrusion. The Woodford granite lies on the same line. These granites lie near a great anticlinal axis, as is frequently the case with anticlinal structures of great magnitude.

The quartz-mica schists are wholly crystalline, and are developed in the neighbourhood of granitic intrusions. In the hand specimen the rock is usually white in colour, but is sometimes stained reddish or brownish by iron oxide. The constituent minerals are quartz, biotite, and muscovite. The minerals are segregated into layers, often producing a coarsely gneissic appearance. The rock is completely crystalline. The cleavage as a rule takes place along roughly plane surfaces parallel to the foliation, but sometimes the rock has been bent into many small puckers and the cleavage becomes irregular.

Under the microscope the quartz is minutely granular, the grain size rarely exceeding ·1 mm. in diameter. Brown biotite occurs in narrow flakes with their long axes parallel to the foliation. They are segregated into narrow bands through the quartz. Muscovite occurs in the bands of biotite. Limonite is plentiful in weathered specimens. Other minerals than these have not been noted.

The phyllites are monotonously uniform over wide areas between Brisbane and Dayboro'. A traverse from Cedar Creek to Cash's Crossing on the South Pine River was entirely over such rocks. The distance between these two places, measured in a straight line, is approximately seven miles. The direction makes an angle of about 45 deg. with the strike. The angle of dip is at first quite small, but to the east it increases after about two miles have been traversed and at the end of the traverse is about 60 deg. We may assume that the average dip is 45 deg. Thus, if there is no duplication of the strata by strike faulting, the thickness is approximately 18,500 feet. Beyond Cash's Crossing the Schist is covered by Tertiary strata, so that this estimate is quite a conservative one.

There is no doubt that the metamorphism of much of the quartz-mica schists is due chiefly to the great granitic intrusions which pierce the Schists at intervals along the north-north-west and south-south-east axis already referred to. Regional metamorphism, however, has also played its part, and there is no doubt that the mica phyllites remote from the granites result from this type of alteration.

Summary of Section VI.

The mica phyllites are typically developed between the North Pine River and Brisbane. They also occur to the east of Kingston and on

Russell and Lamb Islands. They are altered by intruded granites to quartz-mica schists, cyanite-rutile granulites, chiastolite schists, &c. Estimated thickness, 18,500 feet.

VII.—Relation of the Greenstone and Mica Phyllites.

A section that gives a clue to the relation between the greenstones and the altered sedimentary series is that mentioned earlier from Kilcoy. Here greenstones are with interbedded (?) mica phyllites striking east and west and dipping to the north. Mr. C. H. Massey has informed the writer that towards the junction of the schists with the Mesozoic sediments west of Kilcoy the strike of the former is north-east and south-west, with a dip to the north-west, the rocks here being mica phyllites. Thus it is evident that the greenstone underlies the mica phyllite. This relation is borne out by other sections, for, although no actual junction can elsewhere be found, the dips always suggest that the phyllites overlie the greenstone. For example, at Dayboro' the mica schist lies to the west of the greenstone and both have a westerly dip, and similarly at Kobble. On the east we have mica phyllites and slates apparently interbedded with the greenstone, but the disturbances here have been such as to conceal the true relationships. There is a junction of the greenstones and the mica phyllites extending from Petrie across the strike to Kobble which follows approximately the course of the North Pine. No greenstone has been found south of this line. There can be little doubt that the junction is a faulted one, the southerly beds having been dropped down with respect to those on the north side of the junction. It seems clear that the oldest members of the Brisbane Schists exposed are the greenstones, and that these are overlaid by mica schists of sedimentary origin which pass upward into phyllites, slates, quartzites, and shales. Further it appears that this sequence is a conformable one, no basal conglomerates or unconformities appearing at any point in the series. These conclusions have been strengthened by the finding by Mr. C. H. Massey of greenstone very similar to the Petrie greenstone on the east coast of Stradbroke Island adjacent to Russell Island, where it undoubtedly underlies the mica phyllites.

VIII.—The Neranleigh Series.

This series, described by Rands [11] in 1889, includes the felspathic sandstones, shales, "conglomerates," and grits that have their typical development at Mudgeeraba. The Neranleigh beds have been noted at Currumbin, West Burleigh, Mudgeeraba, and in many places between there and Bethania Junction. Greywacke forms high precipitous hills at Tambourine Mountain, and occupies much of the east side of the mountain. It is found just north of Alberton, and from here north to the junction with the Mesozoic rocks. Greywackes and shales occur between Carina and Greenslopes. At Kenmore, some three miles west of Indooroopilly, there occur somewhat sheared greywackes with green calcareous slates. It is inferred from the great abundance and size of the boulders of greywacke found in Leacey's Creek, near Dayboro', that this rock outcrops in the hilly country at the head of the stream, a few miles west of its junction with the North Pine River.

Certain information obtained from Mr. C. C. Morton, of the Queensland Geological Survey, led the writer to visit Mudgeeraba, whence a traverse was made to Neranwood, a small settlement some eight miles distant in a south-westerly direction. The traverse was made by way of the tramway, and the return journey by the road, very good sections being seen on both routes. To the north of the Mudgeeraba railway station there are excellent sections exposed in the cuttings. North of the station a massive series of grits outcrops. Included in the grit are patches—generally elongate and cut off at one end abruptly—of very fine shale. Scattered sparsely throughout the grit are rounded boulders and angular pebbles of two kinds:—(*a*) a quartz-felspar rock, and (*b*) quartzite, sometimes banded. Some of the boulders are approximately spherical, but the majority are somewhat irregularly shaped. One boulder seen by Mr. Morton was 2 ft. long by about 1 ft. by 18 in. The author has seen several boulders near Nerang up to 3 ft. in length. (*See* Plate VII., fig. 3.) The quartz-felspar rock has phenocrysts of quartz and felspar set in a groundmass of the same minerals. Occasional chlorite stains indicate the former presence of very subordinate ferro-magnesian minerals. Under the microscope the rock is seen to consist of phenocrysts of (1) quartz, clear and free from cracks and inclusions; (2) plagioclase somewhat kaolinised; (3) orthoclase; and (4) microcline, both rather clouded. The fine-grained groundmass is composed of these four minerals. There is a notable absence of ferro-magnesian constituents. Most of the boulders are of this type. As far as is at present known there is no such rock outcropping in southern Queensland, so that this occurrence is of great interest, being the sole relic of a once important rock mass, now completely eroded or covered by sediments.

Quartzite boulders are rare. They consist of black or reddish quartzite that split readily along a series of parallel planes (foliation planes).

As one proceeds along the tramway line, fine-grained compact shales are met with. Prolonged search revealed no trace of any organism. Thin bedded quartzites stained with manganese are exposed in a quarry situated at the first turn in the tramway. The beds are contorted in a peculiar manner and exhibit miniature anticlines, synclines, overfolds, and faults. Massive greywacke, boulder beds, and manganiferous quartzites occupy the rest of the section. Dips, where they can be observed, are all in an easterly direction.

At Neranwood there are massive quartzites, often brecciated in appearance and containing innumerable veins of turquoise which, although generally pale-green, occasionally takes on the beautiful blue colour that has made turquoise a valued gem. The quartzite is overlaid by manganese-bearing clays which strike north-west and south-east and dip at an angle of 45 deg. to the north-east. After half a mile these pass upward into a reddish cherty mudstone that contains myriads of casts of radiolaria. The radiolarian rocks grade upward into dark-grey shales which appear to be unfossiliferous.

The radiolarian and associated rocks are cut off on the east by a fault striking north and south. The absence of these beds only a few miles to the north and their faulted nature suggest that they represent a faulted outlier.

Between Mudgeeraba and West Burleigh there occur grits, ''conglomerates,'' greywacke, and banded shales, striking approximately N.N.W. and S.S.E. and dipping to the west. Evidently there occurs a syncline here with its axis passing through Mudgeeraba. At West Burleigh, greywackes overlie silicious shales, sandstones, mudstones, and quartzites.

The quartzites have more or less felspar, and form hard, weather-resisting cliffs at North Burleigh and Currumbin. At Tugun micaceous shales occur, bearing indistinct plant remains. The mudstones of Burleigh Heads and Tweed Heads also contain indeterminable plant remains. These fossils have always been regarded as fragments of marine algæ, but no special study has been made of them, and in any case they are probably too fragmentary for classification. They consist of elongate carbonaceous markings usually exhibiting no structure. Occasionally there is to be seen a median depression that may represent a mid-vein.

Similar rocks occur to the south-east of Murwillumbah in New South Wales. They have been traced as far south as Cape Byron, where the dip is in a westerly direction. Here manganese dioxide occurs in lenticles and veins in clay slates and thin-bedded quartzites.

At the north end of Tambourine Mountain the lower basalt rests partly on Mesozoic sandstone and partly on the greywacke, both of which series it has intruded, for dykes of a basaltic nature are seen cutting them in several places. On crossing the boundary between the basalt and the greywacke, Cedar Creek drops down several hundred feet over a series of falls and rapids. It has cut a deep gorge with one wall over 200 ft. high, exposing a vertical cliff of massive greywacke. The greywacke here shows no traces of bedding, is remarkably homogeneous, and is traversed by an unusually uniform system of joints, in some of which quartz has been deposited, forming thin veins which persist sometimes for considerable distances in perfectly straight lines. Many angular blocks of the rock, bounded by plane surfaces and approximately rectangular, have fallen into the creek bed from the cliffs. The junction between the greywacke and Mesozoic sandstones is obscured by soil and undergrowth, but in the bed of a small gully about 1 mile west of Cedar Creek Falls there is a beautiful breccia consisting for the most part of large angular fragments of greywacke and slate. This may be a fault breccia. If so, it would give an indication of the nature of the junction between the two series. If one proceeds down the stream one or two basaltic dykes are seen penetrating the greywacke. Lower down, the rock becomes finer in grain, changing to quartzite and having small bands of shale interbedded with it. From these bands the attitude of the strata was determined. The strike is meridional to a few degrees west of north, and the dip vertical. The creek winds for some miles between steep banks of such rocks. An attempt to follow the creek to the Albert River had to be abandoned on account of the thick undergrowth covering its banks. The greywacke is continuous from here in a south-easterly direction to the New South Wales border. Professor H. C. Richards has mentioned the occurrence of fragments of greywacke (microslide in the University of Queensland collection) included in the basalt at Mount Barney. Thus the Neranleigh beds are probably much more wide-spread than would appear from their limited outcrop along the coastal strip.

An interesting section occurs between Loganholme and Stradbroke Island. Thin-bedded quartzites associated with a deep reddish fertile soil are the most westerly beds; they are more or less vertical and strike N.N.W. Half a mile to the east, greywackes and interbedded shales outcrop, dipping to the west at an angle of about 30 deg. and striking N.N.W. and S.S.E. Further west the shales exhibit traces of schistosity, the dip still being to the west. Towards Native Dog Creek the soil assumes a deep-chocolate colour. It appears to be rich and supports many crops. Quartzite was found outcropping in a cutting through this soil. A similar occurrence was noted at Mount Cotton, where the quartzite is manganiferous.

Underlying the quartzite there are beds of clay slate. On Macleay Island, Russell Island, Lamb Island, and Karragarra Island Mr. C. H. Massey has found "clay schists" and mica phyllites striking N.N.W. and S.S.E., and dipping at varying angles to the west. The most westerly outcrop, namely, that occurring on Stradbroke Island, consists of greenstone similar to the greenstones of Petrie. The outcrops of greenstone occur at sea-level and are of very limited extent. It is probable that such rocks form the basement of Stradbroke Island, the surface being occupied by recent sands, &c.

The section is of great value, for it shows very well the relationships of the greywackes, mica-phyllites, and greenstones.

South-east of Brisbane, on the Camp Hill tramway, about 1 mile from the terminus, the dip changes from westerly to easterly, the strike being dislocated. Here again are abundant shales which, like all other occurrences examined, appear to be unfossiliferous.

Proceeding west from Coorparoo the same general succession is met with as on the eastern side. At Buranda the somewhat sheared greywackes disappear under Mesozoic sediments, but a little to the south (at Greenslopes and Ekibin) quartzites are to be seen. The area immediately to the south of Brisbane appears to have undergone much disturbance, for one cannot follow an outcrop for any great distance without meeting an entirely different type of rock from that which one has been traversing.

Greywacke occurs associated with phosphatic quartzites in the neighbourhood of a hill called locally Mount Scrubbytop, some 5 miles south-west of Dayboro'. The rock is somewhat sheared. Further north more massive greywacke evidently occurs. Large boulders of it are to be seen in the North Pine River and Leacy's Creek, near the confluence of these streams.

The course of the greywacke further north has not been followed, mainly on account of the hilly and inaccessible nature of the country. There is evidence that it has suffered considerable disturbance, because along the line of strike near Kilcoy we have rocks of a very dissimilar nature.

Greywacke has been encountered in the Coff's Harbour schists not far from the type locality. The rock is associated with red soil, and outcrops are numerous. Under the microscope the constituent grains of quartz and felspar (plagioclase, orthoclase, and some microcline) are seen to be rounded to subangular with a fine-grained silicious groundmass. Hornblende and biotite are also present (*see* Plate VI., fig. 5). The rock is not dissimilar to the Queensland greywackes, and may subsequently prove to be part of the same series.

Petrography.—The greywacke* (or arkose), described by Rands [12] as argillacious schist, is variable in its field occurrence and in its textural characters. It may be thin-bedded as at Bethania Junction, where it is frequently interbedded with poorly cleaved slates, and itself contains minute patches of contemporaneous slate; or it may form very massive outcrops, as at Tambourine Mountain, where there is no apparent trace of bedding, and where it forms solid walls hundreds of feet high.

At West Burleigh the greywacke is fawn-coloured and very much like an acidic tuff in the hand specimen. Under the microscope the rock is seen to be made up of angular or subangular grains of quartz and felspar with very little fine material. The quartz is rather clouded with minute dust-like inclusions. The felspar is of three kinds—(*a*) plagioclase, rather decomposed; (*b*) microcline with the characteristic twinning; (*c*) orthoclase, remarkably well cleaved and fairly fresh.

Much of the greywacke at Tambourine is rather silicious and fine-grained. A thin section of a sample taken from Eagle Heights shows the rock to be composed of excessively angular fragments of quartz with a subordinate quantity of felspar, which is also very angular. The average grain-size is about 0·2 millimetre in diameter. The felspar

* The term "greywacke" is used in the sense of Harker ("Petrology for Students") and not in its modern American significance as a basic equivalent of an arkose.

is mostly plagioclase. Fresh orthoclase, green hornblende, and a few small grains of magnetite are also present. The cement is silicious (*See* Plate VI., fig. 4.)

A thin section of greywacke from Pine Mountain, one and a-half miles south-west of Belmont, shows large rounded or subangular grains of quartz and felspar (mostly microcline) and small angular grains of the same minerals. Much decomposed felspar (plagioclase?) is present. There is a subordinate groundmass which is composed largely of silica. A few angular fragments of chert and quartzite are included in the section. Much of the microcline has inclusions of hæmatite and magnetite. Muscovite occurs very sparingly.

Greywacke from Bethania Junction containing small lenticular patches of contemporaneous slate is seen under the microscope to be composed of large subangular grains of quartz, microcline, plagioclase, and orthoclase. The sample being somewhat weathered, some of the felspar is rather decomposed. The lenticles of slate are nearly opaque. They sometimes include small fragments of quartzite.

A fresh sample of massive greywacke taken from a small creek about half a mile south-east of Bethania Junction is seen, under the microscope, to be composed of angular or subangular fragments of dust-clouded quartz, exhibiting strain polarisation, microcline, plagioclase, and orthoclase. Fibrous biotite is plentiful. Magnetite is present in small grains. The groundmass is rather silicious.

A chemical analysis has been made of this rock by Mr. G. R. Patten, of the Agricultural Chemical Laboratory, Brisbane, and is as follows:—

—	A.	B.	C.
SiO_2	68·54	69·73	58·38
Al_2O_3	15·49	14·98	14·47
Fe_2O_3	0·88	1·62	4·03
FeO	3·17	1·66	2·46
MgO	1·23	1·08	2·45
CaO	2·24	2·20	3·12
Na_2O	3·04	3·28	1·31
K_2O	3·50	3·95	3·25
H_2O	0·75 }	0·78	5·02
H_2O-	0·15 }		
CO_2	..	..	2·64
TiO_2	0·59	0·34	0·65
P_2O_5	0·16	0·27	0·17
MnO	0·08	0·11	Tr.
Total	99·82	100·00	100·41

A. Greywacke, Bethania Junction (Analyst G. R. Patten, A.I.C.).

B. Average composition of granites younger than Pre-Cambrian (Osann and Clarke).

C. Composite analysis of shales (R. A. Daly).

For the sake of comparison the average granite (younger than Pre-Cambrian) and average shale are given. The closeness with which the greywacke approximates to the average granite is indeed remarkable, when it is remembered that it is a true sedimentary deposit. The composition is that of an intermediate granite or adamellite.

Very special conditions must have prevailed to permit a great rock mass to be broken down and redeposited without katamorphic agencies having any appreciable effect.

In several other respects the Neranleigh series appears to have been deposited under very special conditions; for example, in the distribution of the boulders, lack of bedding, angular nature of the grits and greywackes, alternating coarse and fine bands in certain localities, banded slaty rocks interbedded with the greywackes.

All these conditions, considered together, are perhaps suggestive of glacial action. The occurrence of undecomposed felspar in the greywacke indicates either an excessively dry or an excessively cold climate, and the angularity of the constituents and the frequent occurrence of slate and shale preclude the likelihood of the deposits being of æolian origin.

In some respects the series resembles a "torrential" deposit, but its wide distribution and great thickness dispose of this mode of origin.

Thus, although the larger boulders in the Neranleigh beds are well rounded, and, as far as examined, free from scratches or grooves, much of the evidence points to a glacial origin for part of the series.

Summary of Section VIII.

The greywackes and banded slates are developed chiefly between Brisbane and Murwillumbah (New South Wales). In the valley of the Nerang River there occur, interbedded with the greywackes, gritty beds containing rounded boulders up to 2 ft. in diameter. For a number of reasons the Neranleigh Series is taken to be a cold-climate deposit and possibly, in part, of glacial origin. The series has been traced as far north as Dayboro'. Thickness unknown; not less than 15,000 ft.

IX.—Relation of the Greywackes and Mica-Phyllites.

There are many sections which show this relation very well. In the section between Loganholme and Stradbroke Island, already referred to, the direction of dip is constant. Greywackes and shales overlie manganiferous quartzose rocks and interbedded basic tuffs (?). Under the quartzites, &c., there are sandy clay slates which pass downwards into mica phyllites (on Russell Island). This sequence has been observed further north in an oblique traverse past Mt. Cotton. In the opposite sense the same sequence is found in a section west from Coorparoo. West from Indooroopilly we find this sequence with the beds dipping to the west again. Both north-west and south-west of Dayboro' we find the same succession.

X.—The Phosphate Belt.

The quartzose rocks usually found at the base of the Neranleigh series present a difficult and at present unsolved problem. In many places they are associated with deep red soils which have often been taken to be of basaltic origin. At Ekibin such red soil occurs associated with a green, very much decomposed rock that is certainly part of the Schist series and is possibly an altered basic tuff. The red soils at Loganholme, Mt. Cotton, and other places are taken by the writer to result from the decomposition of a rock similar to that occurring at Ekibin, notwithstanding the fact that no outcrops of it have been seen.

The quartzose rocks themselves are of obscure origin. Undoubtedly much secondary silicification has taken place, but some part of them at least was originally sandstone or quartzite, as is shown by their texture.

Their thickness varies enormously, and occasionally they almost disappear, as at Adelaide street, Brisbane, where they are represented by a narrow band of thin-bedded cherts.

Here and there the quartzose rocks contain phosphate of alumina in the form of (*a*) turquoise; (*b*) apatite; or (*c*) wavellite. In the Rockhampton area similar deposits have been noted by Mr. B. Dunstan [13]. The mode of occurrence and associated rocks are similar everywhere. This is the most important factor in the correlation of the Keppel Bay–Curtis Island–Gladstone "Schists" with the Brisbane series.

The phosphates were first described by H. G. Stokes [14] in 1892. A full account of the mineralogical and chemical characters was given, but the question of the origin of the phosphates was not dealt with.

Phosphates of alumina have been found in the following localities:—Murwillumbah, New South Wales; Adelaide street, Brisbane; Victoria Park, Brisbane; Wilston Hill, Brisbane; Kedron, Brisbane; Mt. Staypl-ton; Neranwood; Samford; 5 miles S.W. of Dayboro'; Kilkivan district; Emu Park; Curtis Island; Quoin Island; Yeppoon; Keppel Bay (Wedge Island and Divided Island).

The four Brisbane localities are co-linear, the line joining them being the general strike direction. They form a belt five miles long from Adelaide street, Brisbane, to Stafford. In every case the phosphate is associated with quartz. It lines or fills cavities and cracks in cherts, quartzites or quartzose slates. At Wilston and Stafford beautiful green stellate aggregates of wavellite occur in a brecciated chert associated with quartz. In other localities wavellite is absent, or present in small traces only. On the summit of a hill known as Mt. Scrubbytop, about five miles south-west of Dayboro', turquoise occurs in massive quartz veins associated with china clay.

At Neranwood, eight miles south-west of Mudgeeraba on the South Coast railway, there is an occurrence of turquoise similar to that at Mt. Scrubbytop. The Murwillumbah deposits lie on the line of strike of the Neranwood phosphates, some twenty miles away.

The phosphate-bearing rocks at Yeppoon recently seen by the writer bear a striking similarity to those at Brisbane. (*See* Plate IX., fig. 1.) The other phosphate localities are noted in the "Queensland Mineral Index," in which work analyses of the phosphates are given.

Origin of the Phosphate Deposits.—In considering the origin of the phosphates one naturally turns to the nearest deposits of a similar nature whose origin is known, namely, the phosphatic beds in the Mansfield district, Victoria. Skeats and Teale [15] and A. M. Howitt [16] regard the phosphates as being organic in origin. In the associated black cherts there are numerous fragmentary remains of the tests of trilobites, which originally consisted almost wholly of calcium phosphate. The calcium phosphate was dissolved, the solution then coming into contact with aluminous material (clay, &c.), and being precipitated in the form of aluminium phosphate in a more or less hydrated condition.

While there are black cherts associated with the Queensland phosphate deposits, an exhaustive examination of them has revealed no trace of any fossil organism, unless the rather plentiful graphite and other carbonaceous material be taken as such. Furthermore, much calcium phosphate occurs at Mansfield in beds underlying the black cherts. No calcium phosphate is known to occur in association with our turquoise deposits. The black cherts at Mansfield contain the casts of radiolaria, while our cherts, even under the microscope, show no trace of these organisms.

In other respects, such as the confinement of the deposits to one horizon, the narrow width of the deposits, the brecciated and crushed nature of the beds, and association with slates and cherts, the deposits are similar.

On this evidence it would be rash to ascribe the same origin to our phosphates as to those at Mansfield. Wavellite and earthy phosphate of alumina occur near Lancefield (Victoria); hydrous aluminium phosphate occurs at Gingala in the same State, as well as in several other localities, but the origin in these cases is obscure.

Phosphate of alumina occurs in association with calcium phosphate in the Cambrian limestones at Orroroo and other places in South Australia. Here, as well as in Wales, Spain, and U.S.A., the phosphates have undoubtedly been derived from organic sources.

The fact that the Queensland deposits frequently occupy a single horizon precludes the likelihood of their having been derived from a plutonic source, but beyond this nothing definite can at present be said as to their origin.

XI.—The Fernvale Series.

The Fernvale and Pine Mountain jaspers have been described fully by Richards and Bryan [17]. Their relation to the serpentine has been established, and they have been correlated on the one hand with the Woolomin series in New South Wales, and on the other with the jaspers of the Gladstone district. This was the first record of fossils within the Brisbane Schists, and was of great importance in giving support to the correlation of the Pine Mountain and Fernvale serpentine with that of New England (New South Wales). The age assigned to the jaspers was Lower Devonian and to the serpentine Upper Devonian. The Pine Mountain jaspers were reported on by Rands [18] in 1895 and by Ball [19] in 1904.

To the east of Pine Mountain, at a horizon high up in the jaspers, there occur boulders of limestone. They rarely outcrop on the surface, but have been ploughed out of fields in one or two cases. A careful search has failed to reveal any trace of fossils, and indeed the limestone is so crystalline that embedded organisms could hardly have escaped obliteration. These limestones are taken by Richards and Bryan [20] to be the equivalents of the Devonian limestones at Tamworth, Silverwood, and Calliope.

Since the publication of the paper by Richards and Bryan radiolarian jaspers have been found in several other localities. One of these is near Mt. Crosby. Another locality is about three miles east-south-east of the first, and one mile downstream from College's Crossing on the right bank of the Brisbane River. In both cases the jaspers strike at 70 deg. west of north and dip at a high angle to the north. They appear to overlie or to be interbedded with a greenish rock, which may represent an altered tuff with interbedded cherty material. The outcrops are massive and irregularly jointed, so that it is impossible to determine their attitude. A typical outcrop is to be seen in one of the high railway cuttings near the river bridge on the Mt. Crosby railway.

The jaspers in these localities are very massive, making strike and dip determinations a matter of considerable difficulty. In the hand specimen they are identical with the Fernvale jaspers, being red in colour and showing, on a weathered or polished surface, myriads of dark radiolarian casts. Like the Fernvale jaspers, they often contain notable amounts of manganese, but never in anything like sufficient quantity to warrant its being exploited.

The area occupied by the jasper is quite small—only a few acres in all. High bluffs of jasper overlook the river at each locality. The presence of an unusual breccia in the Ipswich series near the more westerly locality suggests that the junction there is a faulted one. If the serpentine ever was represented it has since been denuded or covered with a deposit of conglomerate of the Ipswich series. The jasper occurrences already mentioned occupy their present position by virtue of a series of movements by which the Mesozoic strata have been faulted against the jaspers as suggested by Cameron [21].

Dr. W. H. Bryan informs me that red jaspers occur forming high banks on Barambah Creek, not far from Murgon. Lithologically, they are identical with the Fernvale jaspers, and it is probable that, when examined closely, they will prove to be radiolaria-bearing. The relation of these jaspers to the Kilkivan serpentine is not certain. They lie considerably to the west of the serpentine which is associated with basalts (?) supposed to belong to the Schist series. The cobaltiferous nature of the Kilkivan serpentines marks them as distinct from the serpentines of Pine Mountain, Fernvale, Cawarral, and the New England (N.S.W.) belt. The intense alteration of the surrounding rocks is attributed to the serpentine, which is another important peculiarity of the Kilkivan intrusion. This occurrence may be distinct in age, as it appears to be distinct in horizon from the other serpentines in the Fernvale series.

Red jaspers are reported from the Mary Valley by Mr. E. C. Tommerup. He informs me that outcrops and loose boulders and pebbles composed of jasper are to be seen in numerous localities along the Mary Valley railway. In general they contain no radiolaria, but, near Glastonbury, jasperoid rocks *in situ* were found to contain casts of the organisms. Besides the jaspers, cherts, claystones, and shales seem to be abundant. The whole series seems to have been subjected to intense folding, for anticlines, synclines, and faults on a small scale are to be seen in many localities. Lithologically, the Mary Valley rocks are indistinguishable from the Fernvale series and are regarded by the writer as occupying a similar stratigraphical position to that series, but on the eastern limb of the anticline whose axis passes through Indooroopilly.

Andesitic tuff, striking east and west and overlaid by red radiolarian jaspers, occurs at Brookfield, five miles west of Indooroopilly. The latter are very highly manganiferous, being often stained and riddled with veinlets of the black hydrated oxide. The jaspers are not mentioned by Rands [22] in his report on the area.

They strike N.N.W. and S.S.E. and are overlaid by a very unusual type of rock. It is a green, somewhat calcareous rock which, when split along the bedding, is seen to contain lenticular or angular white bodies up to three inches or more in length. When viewed at right angles to the bedding on a weathered surface the white bodies are very elongate and lenticular and are parallel to one another, frequently conforming to a chain-like arrangement. Under the microscope the rock is seen to consist of chlorite, calcite, and some kaolin-like substance. It is difficult to say how this rock could have originated. It may possibly have been an impure limestone together with volcanic ash, the whole having been subjected to much pressure.

There is a considerable thickness of this type of rock before it grades upwards into banded, often cherty shales, which make a very striking outcrop and remind one irresistably of some of the banded rocks at Tamworth and Woolomin. The banded shales strike N.N.W. and S.S.E. and dip to the west at 45 deg. Overlying them are greywackes and silicious sandstones, which form massive outcrops striking E.N.E. and W.N.W. These grade into dark-green, often banded chert at the Brookfield school, where the strike is N.W. and S.E. and the dip south-westerly.

Such a rock continues across the strike for four miles interbedded with clay slates and calcareous slates which have an average strike a little west of north-north-west. The direction of the dip changes somewhere in this distance. The axis of the syncline cannot be found exactly on account of the very steep dips obtaining, but for the last half mile or so all dips are to the east. In portion 150v, parish of Moggill, there are indurated shales and cherts, some of which are well banded and contain the casts of radiolaria.

The correlation of our radiolarian jaspers with those at Woolomin (of which the writer is an ardent advocate) receives full support from this section, where, as at Woolomin, banded cherts overlie manganiferous red jaspers. The section affords one an opportunity of examining the schists for some thousands of feet above the radiolarian jaspers.

The author has found red jaspers forming high cliffs on the Brisbane River, some five miles east of Fernvale. They are striking approximately north-west and south-east, and are dipping steeply to the south-west. They are associated with cherty rocks, with which they appear to be interbedded.

The country between here and Upper Brookfield is occupied by cherts, quartzites, and indurated shales. The exposures, which are numerous, generally show a rock which is very massive, greenish in colour, and cherty in character. The summits of the mountain chains are invariably occupied by very silicious quartzites, which often form high and inaccessible precipices. The strike remains almost constant at north-north-west and south-south-east, while dips are either vertical or inclined at a small angle to the vertical.

It appears that the rocks in this region have been closely folded and perhaps faulted to a certain extent. Jaspers do not occur between Brookfield and the Brisbane River near Fernvale.

Serpentine occurs about two miles in a direction east-south-east from Fernvale, striking north-north-west and south-south-east. The outcrop, which is only about 80 feet wide, has been followed for 500 yards, and it certainly extends further than this. A southward continuation would probably join up with the Pine Mountain serpentine.

The radiolarian and associated rocks at Neranwood have already been described. Undoubtedly they belong to the Fernvale series, although their exact horizon is doubtful. Whether it is with the Brookfield jaspers that they are to be correlated it is difficult to say, but in their ferruginous character they are closer to them than to the banded cherts.

Certain greywackes and fissile shales occurring at Villeneuve, on the Kilcoy railway, are probably to be included in the Fernvale series. They are certainly much younger than the surrounding phyllites and schists, and, moreover, they have escaped the contact effects of the Neurum granite, suggesting that they were down-faulted to their present position after the intrusion of the batholith.

Note on the Jaspers, &c., of Broadmount and Gladstone.—In 1924, radiolarian jaspers were discovered at Broadmount by Professor Richards and Dr. Bryan [23]. They are associated with serpentine which is striking N.W. and S.E. This jasper is a pink, banded rock containing round casts of radiolaria, and is regarded as being equivalent to the Fernvale and Pine Mountain beds.

Red jaspers were described in 1904 by L. C. Ball [24] from the Gladstone district, apparently overlying Devonian limestones. No trace of radiolaria was seen, in spite of careful search, but we are probably dealing with the same horizon as at other localities, for on the west of the jaspers there are limestones (fossiliferous in this case).

Summary of Section XI.

Jaspers and interbedded andesitic tuffs occur at Fernvale, Pine Mountain, Brookfield, and in the Mary Valley. In all these localities the jaspers contain casts of radiolaria. Intrusive sills of serpentine occur at Pine Mountain and Fernvale. In the former locality, boulders of pure crystalline limestone occur in the jaspers. Banded cherts at Upper Brookfield, some thousands of feet above the jaspers, contain radiolaria, as do some cherty mudstones at Neranwood. Thickness not known; not less than 10,000 feet.

XII.—Earth Movements.

The whole of the rocks comprising the Brisbane Schists have been subjected to intense tangential forces acting in east-north-east and west-south-west directions. As a result of these forces the beds have been highly folded into a series of anticlines and synclines of great magnitude. The lower beds have been rendered more or less schistose by the same forces, and granites have penetrated and now form cores in the great anticline whose axis passes through Indooroopilly and Dayboro'.

The "Indooroopilly anticline" appears to be unsymmetrical. At Cedar Creek we have mica phyllites dipping steeply to the west. Half a mile to the east the beds are nearly or quite horizontal. Further east there is a slight easterly dip, which increases very gradually up to 60 deg. A similar phenomenon is to be observed in the Brisbane area, but there is a crush zone in the neighbourhood of Milton which has the effect of increasing the apparent thickness of the beds on the east of the anticlinal axis.

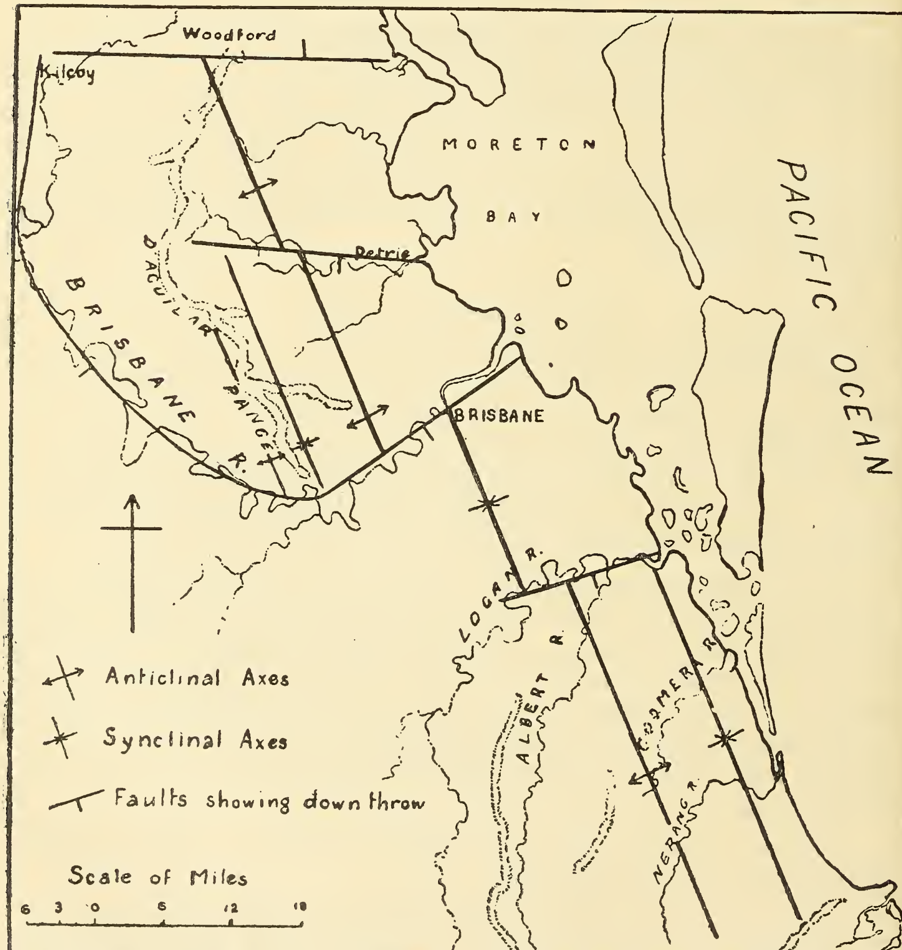
Between Brisbane and Beenleigh this anticline is hidden beneath Mesozoic and Tertiary sediments.

There is almost certainly an anticlinal axis situated between Tambourine and Coomera, but this is difficult to prove on account of the massive nature of the greywackes and quartzites occurring there.

The "Indooroopilly anticline" has been traced as far north as Woodford. The field investigations of the author have not extended further north, and no help is to be had from the scanty literature on the area. It is to be expected, however, that the anticline does continue northward, for it is inconceivable that such a vast structure could suddenly die away altogether.

The "Coorparoo syncline" has already been mentioned. It is a structure of considerable importance, for on its eastern limb the beds continue down as far as the greenstones. Evidence for the continuation of this structure south of Loganholme has not yet been found, chiefly because of the limited field work that has been done there.

At Mudgeeraba there occurs a synclinal axis whose extent has not yet been ascertained. It lies considerably to the east of the Coorparoo syncline, but it is probably part of the same structure.



Text-figure 2.

Diagram showing Chief Structural Features of the Brisbane Schists.

A synclinal axis passes through Upper Brookfield. It is the first of a series of small folds met with as one proceeds from Brookfield to Fernvale.

On the easterly spurs of the D'Aguilar Range, slates and coarse-grained shales occur, dipping in an easterly direction, but on the summit of the range dips are westerly or vertical, indicating a probable anticline.

Between here and Fernvale there is evidence of much close folding. The strata are vertical or severely contorted, making structural deductions very problematical.

Besides the folding along north-north-west axes, there is evidence of several very important faulting movements which have post-dated the folding. These movements have in general taken place approximately at right angles to the folding. The first of them to be noticed is the Petrie–Armstrong Creek fault. The fault follows an approximately straight line between these two places. It is notable that the North Pine River follows much the same course from Dayboro' to Petrie.

The evidence for the fault is as follows:—There is a sudden change in the lithological character of the schists as one proceeds northward along the strike. Mica phyllites are abruptly replaced by greenstone. There is a lack of gradation of one type of rock to the other. Strikes vary considerably in the neighbourhood of the supposed fault. There is a general swinging round of the greenstones to a west-north-west direction—that is, parallel to the supposed fault.

On proceeding in an easterly or in a westerly direction over the greenstones, quartz-mica schist or phyllites, similar to those south of the supposed fault, are met with. On the east they have an easterly dip and on the west they have a westerly dip.

It follows that the south side is the downthrow side.

Numerous small faults have taken place in a direction at right angles to the strike along the course of the Brisbane River. As a result of these there are several faulted inliers of the schists within the Mesozoic series. This zone of faulting is quite extensive, and appears to have affected the Mesozoic rocks for a considerable distance to the south of their faulted junctions with the schists. It swings to the north in the neighbourhood of Fernvale and continues at least as far as Kilcoy.

Another large fault is inferred at the Logan River, where also an abrupt lithological change is to be observed, as one proceeds along the strike. The downthrow side is on the south.

It is believed that yet another east-west fault exists in the neighbourhood of Woodford, for the following reasons:—

Between Woodford and Kilcoy there are to be observed—(1) inliers of younger rocks, and (2) in the neighbourhood of Kilcoy, east-west strikes. To the north of Kilcoy (at Murgon, Wondai, and Kilkivan) there are rocks that are quite high up in the series, while similar rocks are found at the head of the Mary Valley. Thus it seems probable that we have an approximately east and west fault passing through Kilcoy, with the downthrow side on the north. If this is so, the area between Woodford and Dayboro' would represent a "reversed trough" or "horst." The Neurum granite, which is younger than the Woodford instrusion, may be another effect of the same forces that produced the fault.

In the Brisbane district there are several faults (probably in connection with the Brisbane River zone) the extent of which is not yet known. One fault passes through Ekibin and White's Hill. There are almost certainly others to the south of this, and at least one to the north, passing through Coorparoo. The evidence for these faults is (*a*) sudden lithological changes along the line of outcrop, or (*b*) unusual strikes, or sometimes both of these phenomena together.

To the east and north-east of the city of Brisbane there occurs a very unusual series of rocks—the Hamilton schists. W. H. Rands in 1887 (Q.G.S. Rep. 34) described them as "highly quartzose schists." "They probably," he says, "belong to the same series [as the Brisbane rocks], though they differ much in character, being more silicious and not so micaceous."

Under the microscope this rock is seen to consist of irregular grains of quartz that are clear and usually free from cracks. They show "strain shadows" under crossed nicols. The groundmass consists of quartz, muscovite, zircon, tourmaline, hæmatite, limonite, and kaolin, and is entirely crystalline. The muscovite occurs as fine fibres in parallel bands. Zircon is plentiful.

It is not so much the unusual nature of the rock that makes the Hamilton series so striking, but rather its position with respect to the rest of the schists. Although the strike is very irregular, the general direction of the dip is north-east. The passage from the slates of Wilston to these highly schistose rocks appears to be perfectly conformable, and yet it is inconceivable that but slightly cleaved slates could underlie *conformably* a thick series of schists, the foliation and contortion of which must be seen before its intensity can be appreciated.

Furthermore, near Breakfast Creek and at Bulimba there are undisturbed greywackes and slates dipping in an easterly direction. Both of these occurrences are surrounded by quartzose schists, which (at Bulimba particularly) are very highly contorted. They outcrop at low levels, while the surrounding hills are occupied by the quartzose schists.

The only reasonable explanation of these facts which has suggested itself to the author is an overthrust fault. Rocks of a similar type to the quartzose schists, but not so foliated and not contorted, occur at Carina, some seven miles east of Brisbane. Thus the overthrust mass would have moved from the north-east, where similar rocks might be expected to occur (this area is now occupied by Mesozoic sediments).

It is noteworthy that miniature overthrust faults, recumbent folds, and reverse faults do exist in this series.

The existence of a large overthrust fault is rarely easy to prove, and the author does not claim that in this case any one piece of evidence is conclusive, but he does claim that all the facts taken in conjunction strongly suggest that the series of quartzose schists under discussion has been thrust over younger and less altered sediments. The area occupied by the quartzose schists is about five square miles. They are bounded on the north, east, and west by Mesozoic rocks, and on the south by greywackes, shales, and slates.

Faulted junctions of the Schists with strata of Mesozoic age have been noted at Bracalba (Kilcoy railway), Tambourine, and Albion, as well as the localities referred to above.

The Schists are often well-jointed, and some slipping has been known to occur along the joint planes, resulting in slickensided surfaces.

In view of the frequent association of Permo-Carboniferous and Devonian (or older) rocks, the writer believes that (at least in Queensland) folding took place in the Carboniferous period. Dr. F. W. Whitehouse* has recently detected a strong unconformity between Carboniferous and Permo-Carboniferous beds at Lake's Creek, near Rockhampton, a discovery which greatly strengthens the case for Carboniferous folding.

That the great dip faults have post-dated the folding of the Schists is inferred from the fact that in the neighbourhood of the faults the strike of the Schists is profoundly affected, which would not be the case if the faulting had taken place prior to the folding.

Some, at least, of the faulting in the Brisbane River zone is post-Mesozoic, for the junctions of the Schists with the Ipswich series there are faulted.

The age of the Petrie–Armstrong Creek fault is uncertain. At Petrie a fault has brought the Schists up against the Tertiary beds, but it is not comparable in magnitude with the great dip fault, which is probably pre-Mesozoic in age, the Mesozoic rocks being (apparently) unaffected by it.

Benson (Proc. Linn. Soc. N.S.W., 1920, p. 315) and others have

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* I am indebted to Dr. Whitehouse for his permission to use this information in the present paper.

shown that, at the close of the Palæozoic era, Eastern Australia was subjected to heavy epeirogeny, as a result of which Permo-Carboniferous beds have in several cases been block-faulted into older rocks. Since the large dip faults are pre-Mesozoic, it is most reasonable to assume that they are coeval with the block faults at Silverwood, Gympie, Cressbrook Creek, and other places.

Summary of Section XII.

All the beds have been subjected to lateral pressure, resulting in their being folded about north-north-west axes. The major structure is an asymmetric anticline whose axis passes through Indooroopilly. There is an important syncline on the east, and a series of comparatively small folds on the west of the great anticline. Along the main anticlinal axis from Brisbane to Woodford there is a series of granitic masses penetrating the Schists. The strike is fairly constant and rarely departs from the normal direction by more than 15 or 20 degs., except in the neighbourhood of dip faults.

Heavy faulting has taken place since the folding, the most important fractures striking approximately east and west. One of these dip faults passes through Kilcoy. Another passes through Petrie. The Brisbane River follows an east-west fault zone, while another fault zone occurs along the lower reaches of the Logan River. The oldest rocks occur between Kilcoy and Dayboro', the Schists to both north and south having dropped with respect to this region. There appears to be a perfectly conformable passage from the lowest beds to the highest. No disconformities have been detected.

XIII.—Age of the Brisbane Schists.

It must be admitted at the outset that we have no direct stratigraphical or palæontological criteria on which to fix definitely the age of the series.

Almost certainly more than one period is represented. The minimum thickness that we can attribute to the Schists is 75,000 feet, which is more than can reasonably be assigned to one period.

The Brisbane Schists have been assigned the following ages:—

Pre-Cambrian.—David [25], Wearne [26], Saint-Smith [27].

Pre-Cambrian to Carboniferous.—Jensen [28].

Ordovician.—Dunstan [29], Richards [30], David [31].

Ordovician to Devonian.—Richards and Bryan [32].

Silurian.—Rands [33].

Silurian and Devonian.—Bryan [34] [35].

Devonian.—A. C. Gregory [36], Dunstan [37].

Permo-Carboniferous.—Jack [38].

Mr. Dunstan's [39] recognition of certain belts in the schists, particularly in reference to the northern equivalents, was the earliest attempt at subdividing the series and at correlating widely separated occurrences. The belts of Mr. Dunstan are:—

3. Serpentine and limestone,
2. Manganiferous schist,
1. Phosphate-bearing schist.

The official view as to the age of the schists held by the Geological Survey is that they are doubtfully Ordovician. The reason given for this age is that on a certain horizon within the schists there occurs green phosphate of alumina, and this substance is characteristic of certain horizons in the Upper Ordovician sediments of Victoria.

But the age of the Mansfield phosphate-bearing cherts of Victoria has been shown by A. M. Howitt [40] to be Upper Cambrian. Phosphate of alumina has also been found in beds of Upper and Lower Ordovician ages in Victoria. Furthermore, the origin of the deposits cannot be shown to be the same in all cases. Thus an attempt to correlate our phosphatic rock with similar beds over a thousand miles away must lead to confusion.

The possibility that the Brisbane Schists may represent more than one period was first suggested by Jensen [41] and later by Richards and Bryan [42]. The reader is referred to this paper by Richards and Bryan, where a very striking case is presented for the Devonian age of the Fernvale and Pine Mountain jaspers.

The tentative scheme of these authors for the whole of the Brisbane Schists is as follows:—

Serpentines	Upper Devonian.
Radiolarian jaspers	Lower Devonian.
Manganiferous schists	? Silurian.
Phosphatic schists	Ordovician.

In regard to the above arrangement the writer would point out that (at least in the Brisbane area) the radiolarian jaspers are manganiferous, a further argument in favour of the correlation with the Woolomin jaspers which are themselves highly manganiferous.

Additional evidence for the Lower Devonian age of the jaspers is afforded by the presence of banded slaty silicious rocks and cherts that overlie the radiolarian jaspers at Brookfield. The similarity of the banded rocks to certain of those at Tamworth and Woolomin has greatly impressed Dr. Bryan and the writer, both of whom a few months previously went over the entire section in New South Wales.

Dr. Bryan [43] later disagreed with the Ordovician age of the lowest or phosphatic schists, which he now regards as Silurian as a result of approaching the problem from the point of view of earth movements. He found that intense folding had characterised the close of the

Ordovician in Eastern Australia, causing violent unconformities to exist between the Ordovician and Silurian systems. In view of the conformable passage upward from the phosphatic schists to the manganiferous slates, &c., it is most unlikely that the Ordovician period is represented in the Brisbane Schists (*See also* Bryan [44]).

Underlying the phosphate-bearing rocks there is a great thickness of mica phyllite and greenstone, whose age must also be accounted for. To be logical we must assign to these also a post-Ordovician age, since no unconformity has been detected.

The age of the disturbance which produced the folding is probably that of the serpentine, which, according to Benson [45] was intruded in the Carboniferous period. In the author's opinion, it is most unlikely that any folding took place in late Devonian times, for there is no record of any time break between the Carboniferous and Devonian systems anywhere in Eastern Australia. If this is so, the upper part of the Brisbane Schists may have been deposited as late as Carboniferous times.

In the Gladstone area, fossiliferous Devonian limestones apparently underlie red jaspers which are devoid of radiolaria. Further north, however, at Broadmount there occur banded radiolarian jasperoids which are in all probability equivalent to the Gladstone series.

The jaspers and associated manganiferous clay slates are stated to underlie the more easterly phosphatic slates and quartzites, which is an apparent inversion of the succession in the supposed equivalents in the south. The explanation given by Richards and Bryan [46] is that there occurs in the north an overfold causing jaspers and limestones situated near the synclinal axis to overlie the older phosphatic rocks.

If this is correct the parallelism between the Brisbane Schists and the Gladstone–Curtis Island–Yeppoon series is indeed remarkable, and one is certainly justified in correlating them. The northern jaspers would be Lower Devonian and the phosphatic slates and quartzites probably Upper Silurian. The following table shows the close lithological similarity between the two series:—

Age.	Brisbane Schists.	Gladstone-Curtis Island Yeppoon Series.
Carboniferous (?) ..	Serpentine	Serpentine
Devonian ..	Radiolarian cherts, claystones, &c.	Rhyolites, radiolarian cherts, &c.
	Limestone	Fossiliferous limestone
	Manganiferous radiolarian jaspers	Manganiferous radiolarian jaspers
Silurian (?) ..	Greywackes, &c. (sometimes manganiferous)	Manganiferous slates and clay-stones
	Phosphatic cherts, slates, &c.	Phosphatic slates and quartz-ites
	Mica phyllites	(?)
	Greenstones	(?)

Equivalents of the mica phyllites and greenstones are not known in the north. Apparently they are not represented, for on Facing Island, near Gladstone, there occurs a series of highly contorted mica schists striking at 30 deg. east of north and riddled with igneous dykes (*see* Jensen [47]). Although no junction between this series and the Gladstone slates is to be seen, the differences in attitude and lithological character are so marked as to indicate that a sharp unconformity exists. If this is so, the older series is pre-Silurian; according to Bryan [48] it is probably pre-Cambrian.

Summary of Section XIII.

The upper part of the Brisbane Schists may be fairly closely correlated on lithological grounds with beds of Devonian age in Queensland and in New South Wales. It is believed that the Schists do not go below the Silurian on account of the perfect conformability of all the beds in them.

XIV.—Summary.

The name "Brisbane Schists" is applied to an immense series of more or less altered sediments, tuffs, and lavas, occupying a comparatively narrow belt on the south coast of Queensland and extending into Northern New South Wales. In spite of the great variety of rock types represented in the series, there can be recognised four well-marked divisions:—

4. Serpentines, jaspers, andesitic tuffs, banded cherts, shales, claystones, and limestones, to which the name "Fernvale series" has been given.
3. Greywackes, banded slates, grits, boulder beds, quartzites, which have been called the "Neranleigh series."
2. Mica phyllites and quartz-mica schists with phosphatic cherts, slates, and quartzites in the upper portions of the series. This division has been named the "Bunya series."
1. Greenstones, probably altered porphyrites and basalts.

No unconformities or disconformities are known to occur in the Brisbane Schists.

The beds are all folded about north-north-west and south-south-east axes. The major structural feature is an asymmetric anticline whose axis passes through Indooroopilly. Another important feature is a syncline situated on the east of the Indooroopilly anticline. Minor folding is rare except in the Fernvale series.

At least three important dip faults have occurred subsequently to the folding. Small faults are by no means uncommon.

In the absence of palæontological evidence, the age of the Brisbane Schists is not definitely known. The upper part of the series may, however, be fairly closely correlated on lithological grounds with beds of Devonian age in the Rockhampton district and in the Tamworth district in New South Wales. It is believed that the schists do not go below the Silurian on account of the perfect comformability of all the beds in them. Elsewhere in Eastern Australia there is a sharp unconformity between the Ordovician and Silurian systems.

In conclusion, the author wishes to express his gratitude to Dr. W. H. Bryan, of the University of Queensland, for his invaluable assistance and helpful advice in this work; to Professor H. C. Richards and Dr. F. W. Whitehouse, of the University of Queensland, for assistance and encouragement; to Messrs. B. Dunstan and C. C. Morton, A.C.T.S.M., of the Queensland Geological Survey, for valuable information supplied; to Mr. W. Cottrel-Dormer, who has given up much of his valuable time to the photographing of micro-slides, &c.; to Mr. W. H. Reeve for the drafting of the section on page 78, and to Mr. T. K. Smith, of Melbourne, for the drawing of the map showing the distribution of the Schists.

REFERENCES TO LITERATURE.

1. Proc. Roy. Soc. Q'land, 1926, p. 92.
2. Aust. Assocn. for Adv. Sc., 1909, p. 261.
3. Geol. Survey of Q'land, Pub. 225, p. 8.
4. Geol. Survey of Q'land, Rep. 51, p. 5.
5. Proc. Roy. Soc. Q'land, 1924, p. 131.
6. Proc. Linn. Soc. N.S.W., 1906, Part I., pp. 85, 108.
7. Aust. Inst. Engineers (Bris. Div.), 1922.
8. Daly: "Igneous Rocks and Their Origin," p. 400.
9. Grubenmann: "Die Kristallinen Schiefer."
10. Proc. Roy. Soc. Q'land, 1922, p. 123.
11. Op. cit. 4.
12. Geol. Survey of Q'land, Rep. 36, p. 1.
13. Geol. Survey of Q'land, Pub. 190, Part III.; 1904, p. 10.
14. Proc. Roy. Soc. of Q'land, 1892, p. 11.
15. Proc. Aust. Inst. Mining Engineers, 1918, p. 155, et seq.
16. Geol. Survey of Vic., Bull. 46, 1923, p. 8.
17. Op. cit., 5.
18. Geol. Survey of Q'land, Ann. Prog. Rep. 1895, p. 26.
19. Geol. Survey of Q'land, Pub. 194, 1904, p. 55.
20. Aust. Assocn. for Adv. Sc., 1926.
21. Geol. Survey of Q'land, Rep. 143, 1897, p. 13.
22. Geol. Survey of Q'land, Rep. 63, 1890.
23. Op. cit. 20.
24. Op. cit. 19.
25. B.A.A.S., Australia, 1914. Federal Handbook, p. 259.
26. Aust. Assocn. for Adv. Sc., 1911, p. 124.
27. Q'land Govt. Min. Jour., Vol. 24, 1923, p. 412.
28. Proc. Roy. Soc. Q'land, 1911, p. 154.
29. Harrap's Geography of Queensland, Appendix B.
30. Op. cit. 7.
31. Aust. Assocn. for Adv. Sc., 1913.
32. Op. cit. 5, p. 135.
33. Geol. Survey of Q'land, Rep. 34, 1887.
34. Proc. Roy. Soc. Q'land, 1925, p. 16.
35. Op. cit. 1, pp. 92-5.
36. Parliamentary Papers and Proceedings, vol. ii., 1879.
37. Geol. Survey of Q'land, Pub. 241, 1913.
38. Geological Map of Queensland, 1892.
39. Geol. Survey of Q'land, Pub. 268 (Art. 8).
40. Op. cit. 16.
41. Op. cit. 28.
42. Op. cit. 5.
43. Op. cit. 34.
44. Op. cit. 35.
45. Aust. Assocn. for Adv. Sc. 1911, p. 104.
46. Op. cit. 20.
47. Q'land Govt. Min. Journ., vol. 19, 1918, p. 10.
48. Op. cit. 1.

DESCRIPTION OF PLATE VI.

(Figs. 1, 2, 4, 5, by Mr. W. Cottrel-Dormer.)

Fig. 1.—Altered porphyrite, showing groundmass of chlorite and epidote. Stradbroke Island. Ordinary light. Magnification × 120.

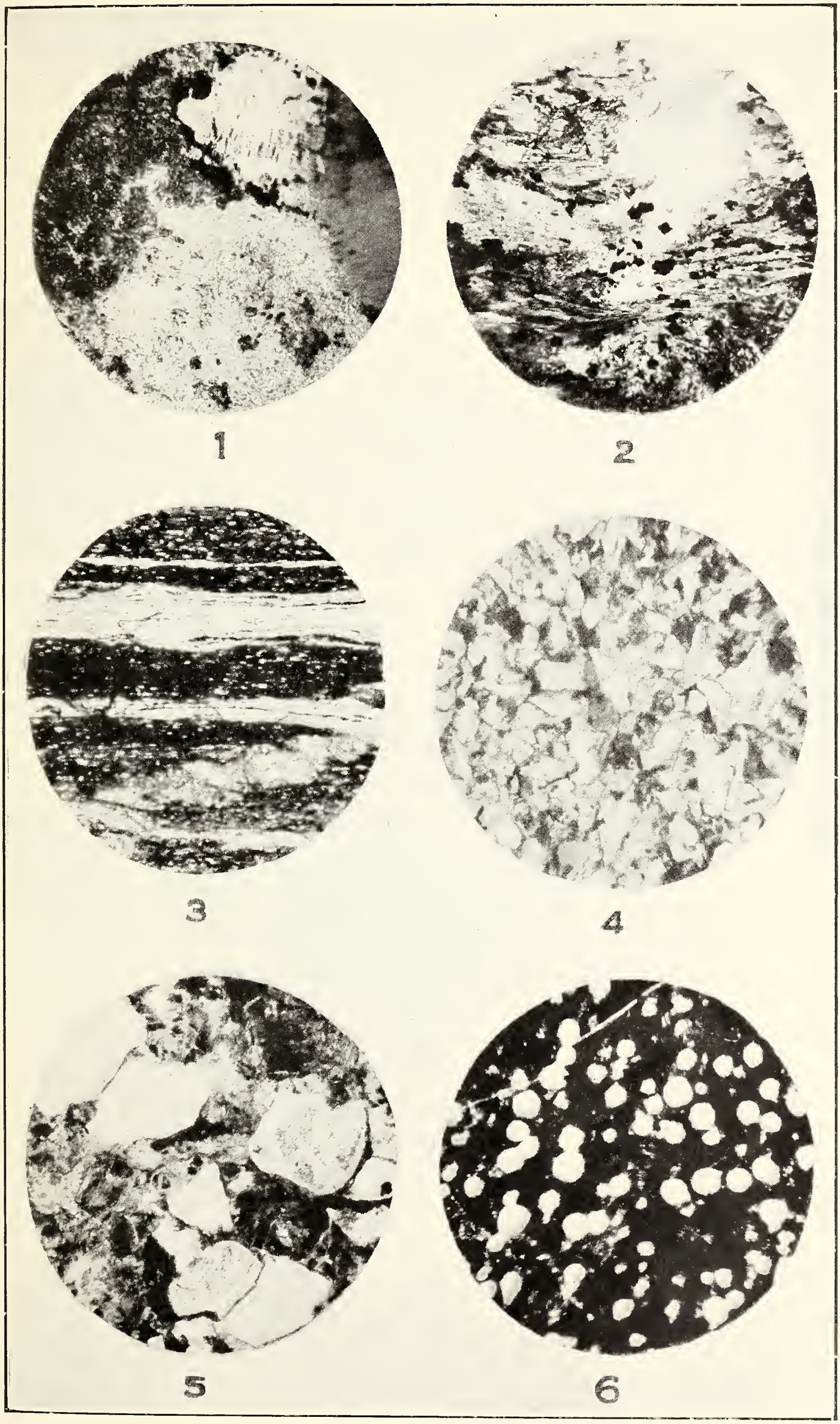
Fig. 2.—Altered porphyrite. Four miles west of Petrie. Ordinary light. Magnification × 28.

Fig. 3.—Phyllite. Adelaide Street, Brisbane. Ordinary light. Magnification × 25. (By kind permission of Prof. H. C. Richards.)

Fig. 4.—Greywacke. Tambourine Mountain. Ordinary light. Magnification × 30.

Fig. 5.—Greywacke. Coff's Harbour, New South Wales. Ordinary light. Magnification × 13.5.

Fig. 6.—Ferruginous jasper with chalcedonic casts of radiolaria. This figure by Prof. H. C. Richards and Dr. W. H. Bryan. Fernvale. Ordinary light. Magnification × 30.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DESCRIPTION OF PLATE VII.

Fig. 1.—Greywacke, showing massive character and jointing. Nerang.

Fig. 2.—Boulders in slate. Two miles south of Nerang.

Fig. 3.—Large boulder of gneiss in slate. Two miles south of Nerang.

1

2

3

Face page 106.]

1.

2.

Fig. 1.—Vertically dipping banded slates. One mile south of Mudgeeraba.
Fig. 2.—Contorted phyllites, showing vein of pegmatite. Auchenflower, Brisbane.

Face page 106.]

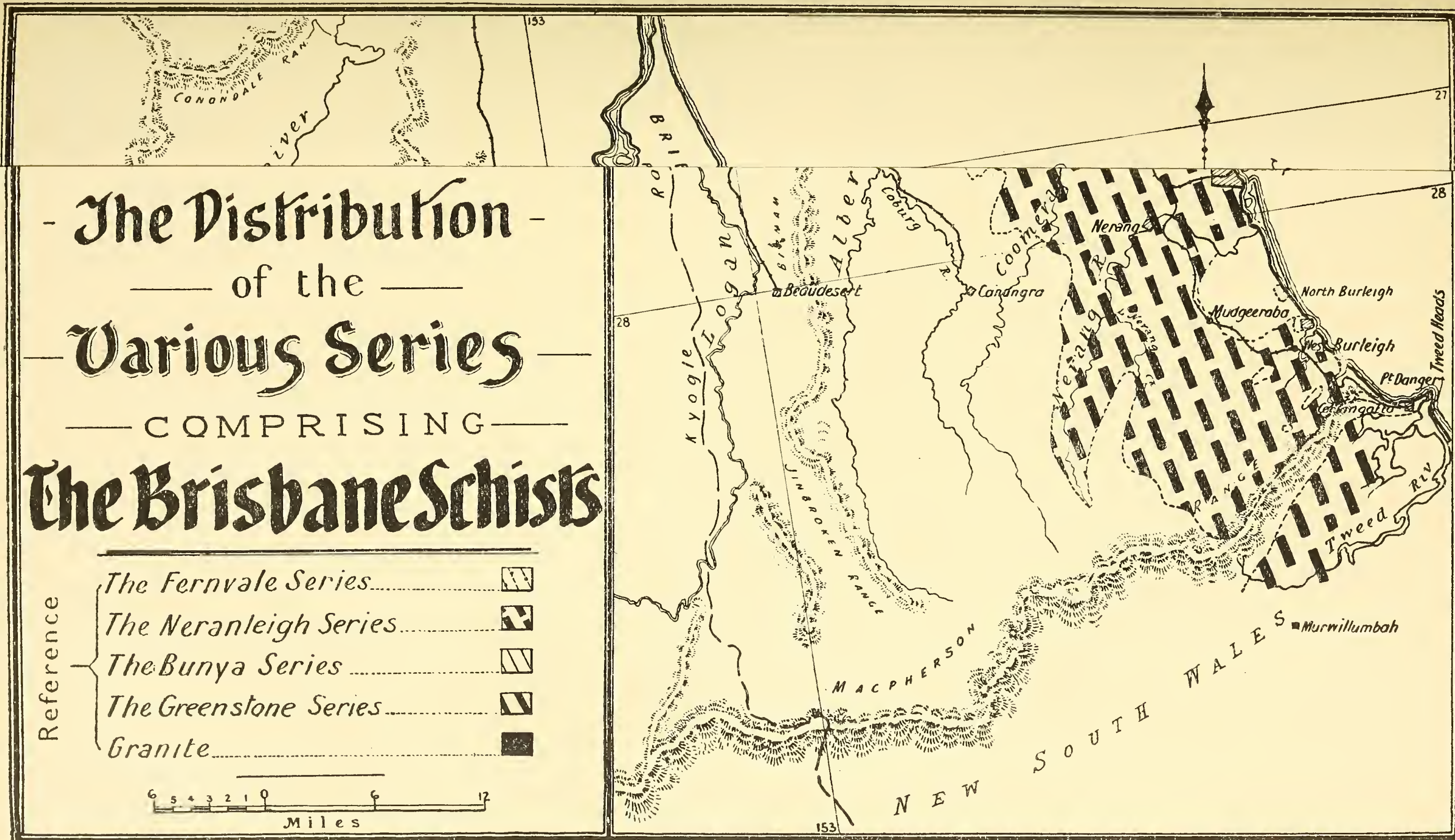
1.

2.

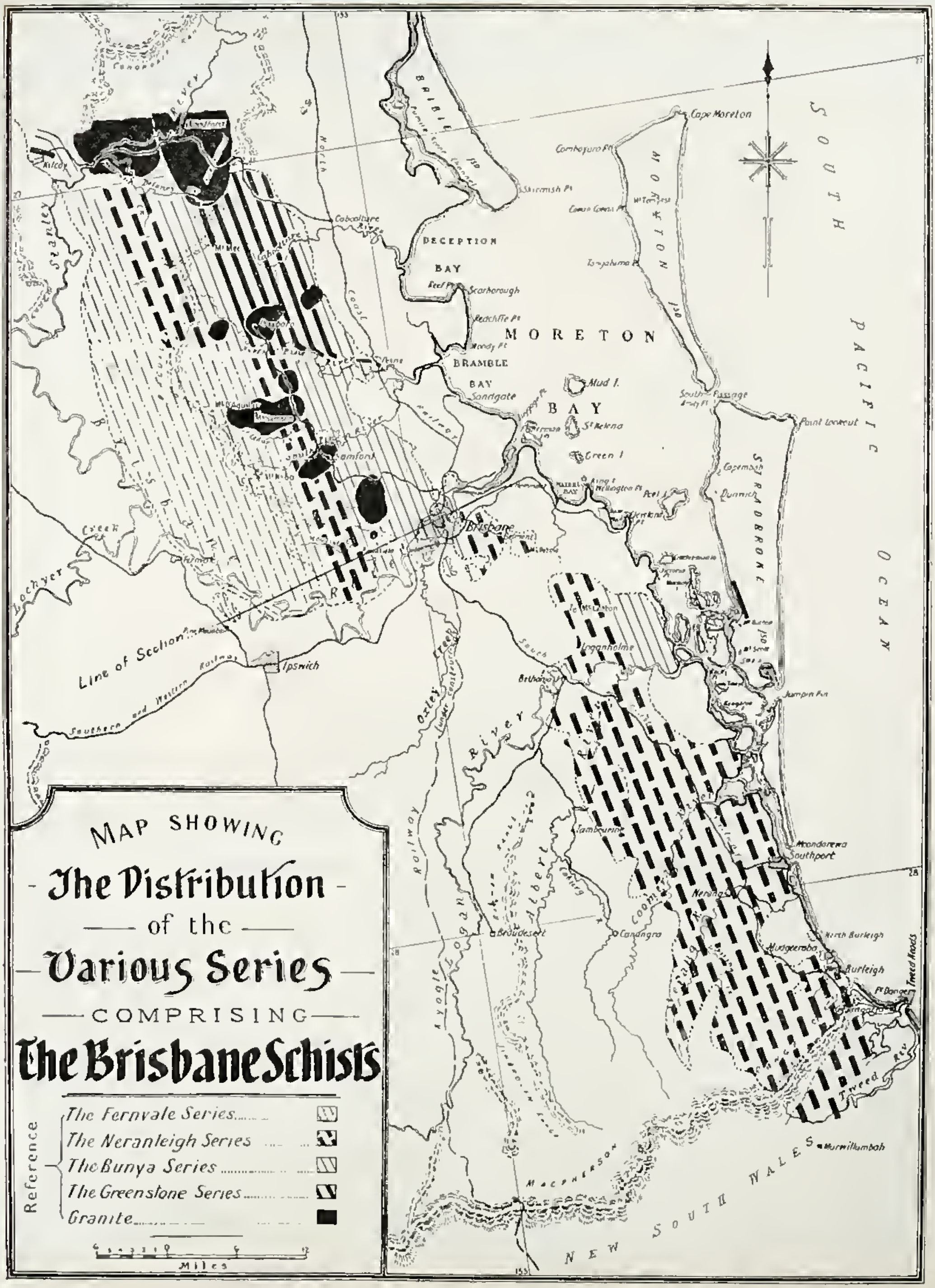
Fig. 1.—Thin-bedded cherts. Yeppoon, Rockhampton district. This is the type of rock most commonly associated with the phosphatic minerals in the Brisbane Schists.

Fig. 2.—Foliated greenstone near Dayboro'.

Face page 106.]



Face page 106.]


MAP SHOWING
The Distribution
of the
Various Series
COMPRISING
The Brisbane Schists
Reference
The Fernvale Series
The Neranleigh Series
The Bunya Series
The Greenstone Series
Granite
Miles
MORETON
BAY
DECEPTION
BAY
BRAMBLE
BAY
SOUTH
PACIFIC
OCEAN
MORETON
STRADBROKE
NEW SOUTH WALES
Cape Moreton
Brisbane
Ipswich
Line of Section
Sandgate
Scarborough
Southport
Burleigh
Beaudesert
Tweed Heads
Murwillumbah

The Rain Forest of the Eungella Range.

By W. D. Francis, Assistant Government Botanist.

Plates XI. to XIV.

(*Read before the Royal Society of Queensland, 31st October, 1927.*)

I. Introduction.
II. Climate and soil.
III. Vegetation of the foot hills.
IV. Some conspicuous constituents of the forest.
V. The occurrence together of northern and southern species of the Queensland Flora.
VI. Comparison with the flora of other mountain areas.
VII. Discussion.
VIII. Summary.
Appendix—List of plants collected on the Eungella Range.

I. Introduction.

The Eungella Range is situated in Queensland, about forty five miles westward of Mackay, at approximately 21° south. The vegetation consists chiefly of dense rain forest, similar in general character to the heavy rain forests of other parts of the State. Likewise the majority of the species are allied to species of the rain forests of Papua and Malaya. As the area is situated about midway between the comparatively large extent of rain forest of Southern Queensland, with Maryborough as its northern limit, and the tropical rain forest of the Cairns district, it is of some interest from the standpoint of the plant geography of the State. A brief botanical survey of this intermediate area, which the rain forest of the Eungella Range represents, is of service in elucidating the distribution of species in some instances regarded as limited to the southern rain forest and in other instances to the northern one.

Another factor involved is that of elevation. The area of the Eungella Range examined by the writer varies from 2,300 to 3,000 ft in height. An outline of the vegetation of this area would facilitate a comparison of its botanical constituents with those of similar elevated and lowland areas in other parts of the State. It is recognised, however, that, owing to the absence of very high mountains in Queensland, the study of plant distribution in relationship to altitude is limited. The floras of some of the more interesting elevated areas in the State, such as the Bellenden-Ker Range, Macpherson Range, and Bunya Mountains, have received attention from botanists in the past.

The present paper is based upon a short visit by the writer to the Eungella Range from 3rd to 12th October, 1922. The part of the range visited was that above Netherdale, the terminus of the railway line from Mackay, whence a road leads up the range.

II. Climate and Soil.

The rainfall, humidity, and temperature, as well as the character of the soil, undoubtedly have influenced to a great degree the distribution of rain forest in Eastern Australia. The presence of this type of vegetation on so many of the mountain ranges of Queensland is due mainly to these factors being favourable to its development. The Macpherson Range, Mount Mistake, Tambourine Mountain, and Blackall Range are examples of the coincidence of heavy rainfall, basaltic soils, and rain forest. As the equator is approached the relative importance of soil conditions is not so evident, because the increasing temperature and humidity in combination with a heavy rainfall appear to be sufficient to maintain rain-forest growth on comparatively poor soils.

In reply to an inquiry, Mr. H. A. Hunt, the Commonwealth Meteorologist, states that the average annual rainfall of the Eungella Range is 65 in. The eastern part of Queensland adjoining the coast contains six regions with a rainfall approximating or exceeding 60 in. per year*. Separating each of these regions are areas in which the rainfall is markedly less. This distribution of rainfall has a very noticeable effect on the location of luxuriant rain forest in the State, as it is in the regions of the heavy rainfall that the luxuriant rain forests are found. With the exception of the limited area around and northwards from Yeppoon, the fairly extensive, heavy-rainfall belt, including Mackay, the Eungella Range, and Proserpine, is the only markedly moist region between the rain forests of Southern Queensland and of the Cairns region. The temperature of the Eungella Range would be similar to that of a region between Southport (28 deg. S.), Queensland, and Grafton (30 deg. S.), New South Wales, if calculated on the basis adopted by Sir J. D. Hooker [1]. Hooker assumed that at each 1,000 ft. of elevation the temperature corresponds to that of a position at sea level three degrees further from the equator. The soil of the area is derived from a granitic rock. Two rock samples collected by the writer from the road cutting ascending the range were identified by Professor H. C. Richards as horneblende granite and hornfels. Mr. L. C. Ball [2] refers to the common rock of the locality as granodiorite.

III. Vegetation of the Foot Hills.

The country at the foot of the range consists partly of Eucalyptus forest, which is found on some of the dry ridges, and partly of rain forest, which clothes the valleys and banks of watercourses. The road

* These areas are enumerated by the writer in a paper in these Proceedings, Vol. 34, p. 210, 1923.

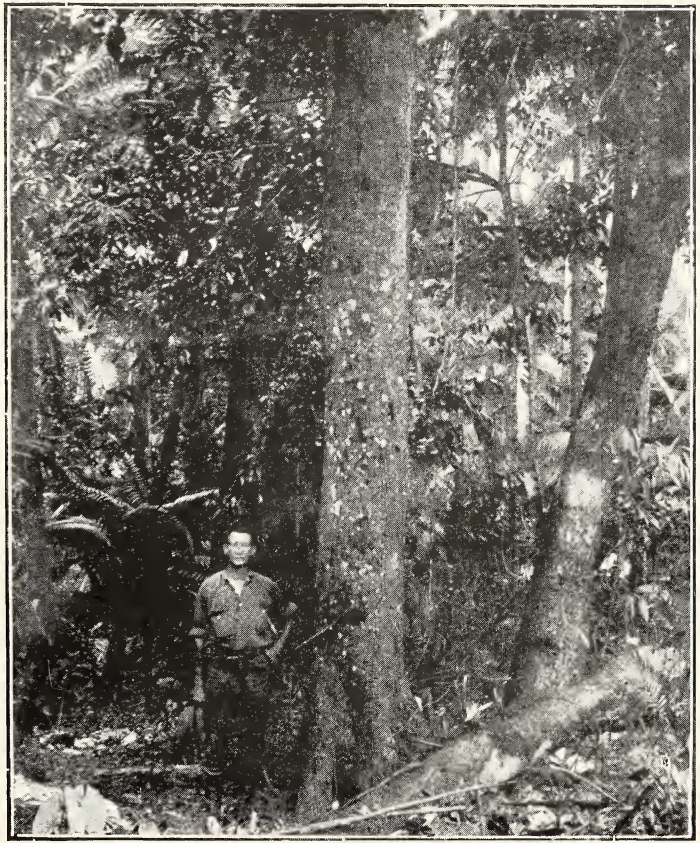


Fig. 1.—MYRISTICA INSIPIDA R.Br., at foot of Eungella Range near Netherdale. The palms in background are Archontophœnix sp.

Fig. 2.—CEDRELA TOONA Roxb. var. australis C. DC., a large red cedar tree. Eungella Range. The climbing Pandanaceous plant, *Freycinetia excelsa*, is conspicuous on left and right side of picture.

Photos. : W.D.F.

up the range passed through rain forest mainly, and it was in this type of vegetation that the trees referred to in this paragraph were observed. One of the principal trees noticed was the native nutmeg (*Myristica insipida*), which is a tropical species. The trees seen were short-stemmed and attained a height of about 70 ft. The appearance of the bark, which is brown in colour, is represented in the photograph (Fig. 1). The species does not appear to extend beyond 1,000 ft. on the range. The milky pine (*Alstonia scholaris*) attained a large size in the valleys and was not seen in the higher parts of the mountains. A feature of this species is its peculiar stem, which is triangular or quadrangular in cross-section towards the base. One example of the Mackay cedar (*Albizzia Toona*) was seen. It was a typical rain-forest tree with a very long stem. It was leafless at the time of the visit (October) and is probably a deciduous species. *Timonius Rumphii* forms a fairly dense undergrowth on some of the lower slopes. In the valleys there were large numbers of the Northern Bangalow palm (*Archontophœnix Alexandræ*), which is similar in appearance to the Bangalow palm (*Archontophœnix Cunninghamii*), which extends much further south. The white or grey colour of the underside of the leaves readily distinguishes the northern species referred to. Along the roadside up to about 1,200 ft. *Trema orientalis* is plentiful. Unlike its congener, the peach-leaf poison bush (*T. aspera*), it is a tree attaining a height of about 50 ft. and a stem diameter of about 15 in.

IV. Some of the Principal Constituents of the Rain Forest of the Range.

The writer was impressed by the large number of red cedar trees (*Cedrela Toona* var. *australis*) in the rain forest. Up to that time suitable access for timber haulage was not available and the area was almost in its primeval state, but the felling and removal of some of the cedar trees had begun. One of the most common trees is the species known in Southern Queensland as black jack (*Tarrietia actinophylla*). It is very closely allied to the booyong or Queensland hickory (*T. argyrodendron*), a tree which it closely resembles in appearance. Like the booyong, the black jack is always buttressed and has a slightly furrowed bark. Partly detached pieces of the bark generally reveal a darker-coloured inner bark. The stems of both species above the buttresses are generally fairly cylindrical and elongated and their taper upwards is less evident than in other trees. The prevalence of the black jack in Eungella Range forests corresponds to the frequent occurrence of the booyong in South Queensland lowland rain forests. A few trees of the booyong were noticed in western portions of the Eungella Range forests. Another large rain-forest species which is very common in the area is *Elæocarpus foveolatus*. It is abundant at an altitude of about 3,000 ft. on the track leading to Mt. Dalrymple. It has a light-grey, fairly smooth bark and a buttressed stem. The foliage looked at from the ground beneath the trees is brown in appearance. Very large numbers of Bangalow palms (*Archontophœnix Cunninghamii*) were also found along the track to Mt. Dalrymple at about 3,000 ft. In places these palms were the predominant constituent of the forest. The Northern Bangalow palm (*Archontophœnix Alexandræ*) appeared to be comparatively rare in the upper parts of the range.

A tree with a very corrugated sapwood surface, and on that account called the washing-board tree, is fairly common. It proved to be a new species, and was named *Cryptocarya corrugata* by White and Francis in these Proceedings [3]. A large proportion of the undergrowth in places was composed of *Drimys dipetala* and *Sloanea Langii.* The Eungella gums, which comprise two species known as red Eungella gum and white Eungella gum, are important trees, as their timber is used by the settlers as a substitute for hardwood. The timber is said to be fairly durable. The red Eungella gum is *Eugenia hemilampra.* The white Eungella gum also belongs to the genus *Eugenia*, but the species may be undescribed. In outward appearance the two species are often very similar. They are both buttressed trees with grey to brown barks. (See Figs. 3 and 4.)

The common lawyer palm of the area is *Calamus australis*, which is very frequent throughout the rain forest, and climbs over the shrubs and trees. Many of the tree stems are more or less enveloped by *Freycinetia excelsa*, and large clumps of the elkhorn fern (*Platycerium alcicorne*) are situated on the branches and upper parts of the tree trunks.

V. The Occurrence together of Northern and Southern Species of the Queensland Flora.

The following are some of the tropical species which were found in the rain forest :—*Cryptocarya Murrayi, Cinnamomum Tamala, Sloanea Langii, Mallotus angustifolius, Elæocarpus ruminatus, E. foveolatus, E. sericopetalus, Xanthophyllum Macintyrii, Bœa hygroscopica,* and *Calamus australis.*

The following species, hitherto regarded as belonging to Southern Queensland or, in some cases, to Northern New South Wales also, occur on the Eungella Range :—Corduroy tamarind (*Arytera Lautereriana*), Queensland beech (*Gmelina Leichhardtii*), carribin (*Sloanea Woollsii*), mountain beech (*Elæocarpus Kirtonii*), mango bark (*Protium australasicum*), black jack (*Tarrietia actinophylla*). So far as known previously, the northern limit of these species was Fraser Island (25° S.).

The mingling of species from northern and southern parts of the State may be accounted for by the intermediate position of the Eungella Range and its altitude, which affects the climate by reducing the temperature. This effect of altitude may be a determining factor in the distribution of the species referred to above as southern species extending to the Eungella Range. The distribution of the hoop pine

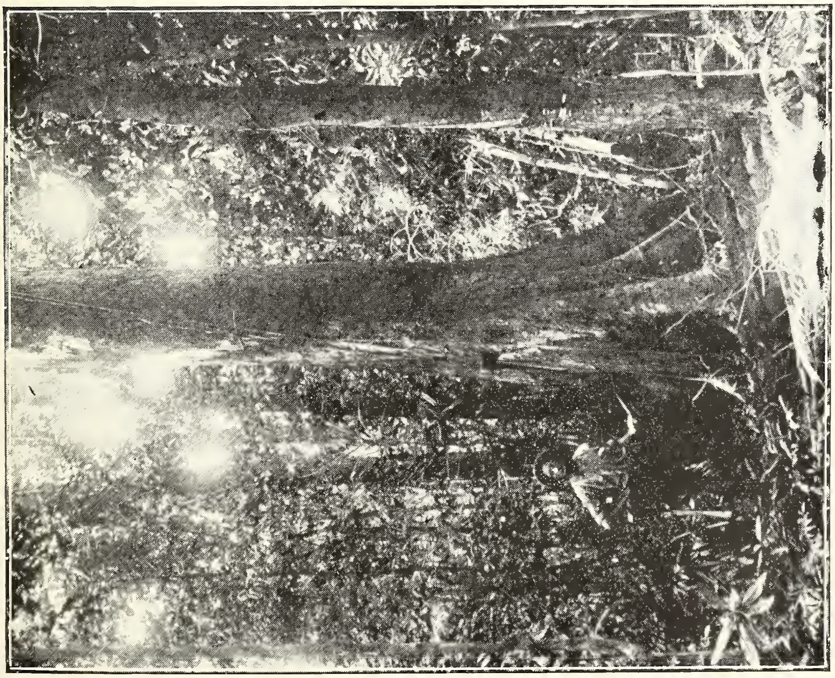


Fig. 3.—EUGENIA HEMILAMPRA F.v.M., red Eungella gum. Eungella Range. The ærial roots of a fig tree are shown on the stem.

Fig. 4.—EUGENIA sp., white Eungella gum. Eungella Range. Two large trees of the species are shown in picture.

Photos.: W.D.F.

Fig. 5.—ELÆOCARPUS RUMINATUS F.v.M. Eungella Range. The abundance of the Bangalow palm (*Archontophœnix Cunninghamii*) is indicated by this picture.

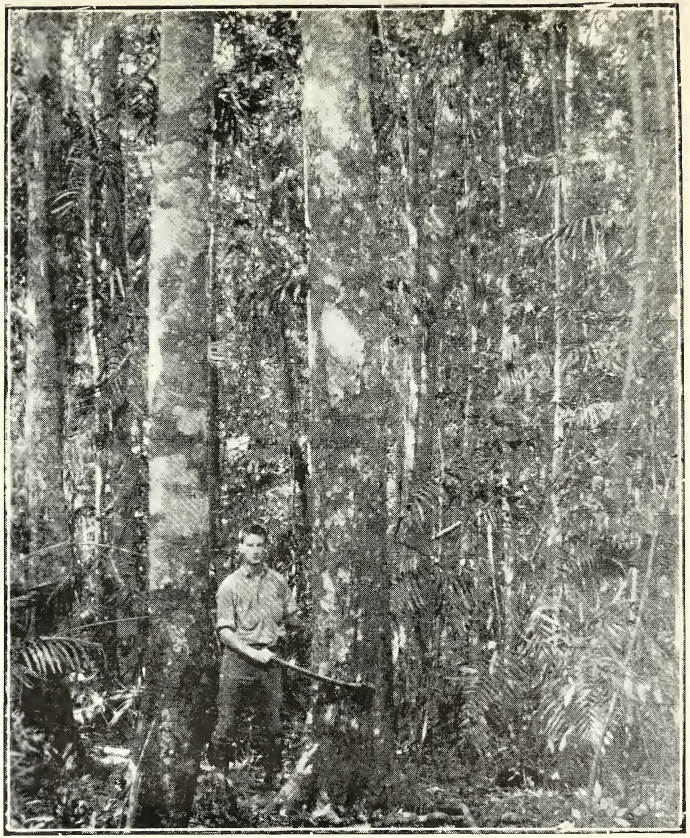


Fig. 6.—CRYPTOCARYA CORRUGATA White & Francis, washing-board tree. Eungella Range. The palm-like leaves of *Calamus australis* are a feature of the background.

Photos.: W.D.F.

Fig. 7.—CINNAMOMUM TAMALA T. Nees. Eungella Range. The remaining tree stems shown in picture are of the Bangalow palm (*Archontophœnix Cunninghamii*). The leaves of this palm compose the greater part of background of picture.

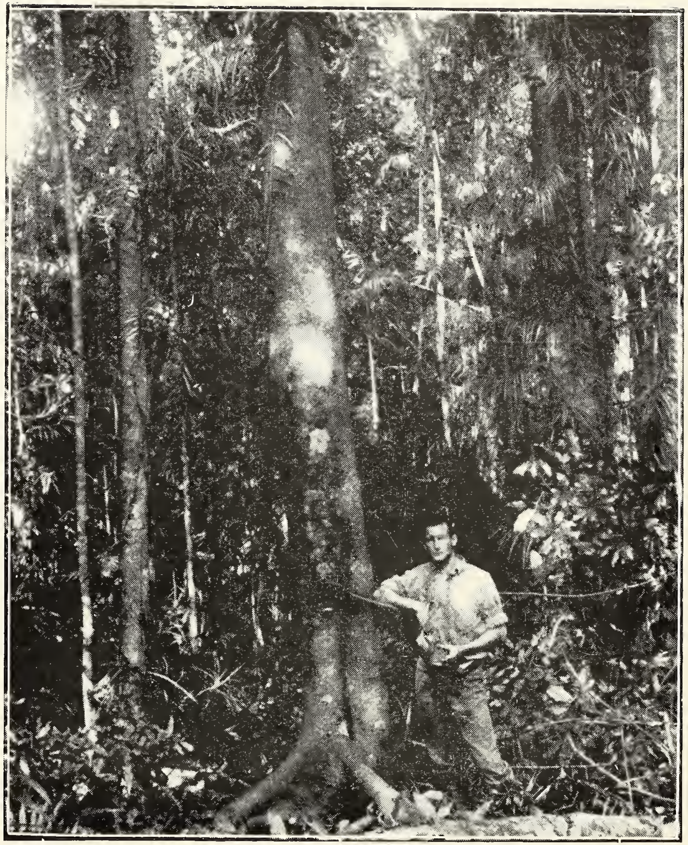


Fig. 8.—HYMENOSPORUM FLAVUM F.v.M. Eungella Range. The Pandanaceous climber, *Freycinetia excelsa*, is shown ascending the stem in the upper part. The same species of climber is copiously represented in the upper right and left of picture.

Photos.: W.D.F.

(*Araucaria Cunninghamii*) in Eastern Australia and Papua exhibits a similar relationship to altitude. In Queensland it grows on the lowlands and ridges, whilst in Papua, as pointed out by C. E. Lane-Poole [4], this species is no longer a coastal one but appears at about 5,500 ft. and ceases at about 7,500 ft. on the mountains.

VI. Comparison with the Flora of other Mountain Areas.

In considering the relationship of the flora with that of other elevated areas, it is found that a number of species or their allies are common to elevated areas in widely separated parts of the State. The Magnoliaceous genus *Drimys* has a still wider range, extending to mountain areas of Eastern Malaya.

It has already been stated that the black jack (*Tarrietia actinophylla*) is one of the commonest trees on the Eungella Range. This species also occurs very frequently in the rain forest of some South Queensland mountains such as the Macpherson Range at Roberts Plateau, and near Killarney. J. H. Maiden [5] records the same species as plentiful on the Dorrigo, a mountain area of New South Wales. Another species, the mountain beech (*Elæocarpus Kirtonii*), which is abundant on the mountains of South Queensland, is also found on the Eungella Range. *Symplocos spicata*, a large tree, which is plentiful in the rain forest of the Eungella Range, is closely allied to, if not identical with *Symplocos Thwaitesii*, which Miss L. S. Gibbs [6] observed on Mt. Bellenden-Ker from 3,000 to 5,000 ft.

Species of the genus *Drimys*, although they are not confined to elevated areas in Eastern Australia, are important constituents of mountain areas throughout a wide range. The abundance of *Drimys dipetala* in parts of the rain forest of the Eungella Range has been remarked upon in this paper. J. H. Maiden [5] states that *Drimys aromatica* forms large areas of the undergrowth of the Dorrigo. On Mt. Bellenden-Ker, Miss Gibbs [6] found that *Drimys oblonga* forms dense scrub on the summit at 5,000 ft. In recording *Drimys piperita* for Mt. Kinabalu, North Borneo, O. Stapf [7] remarks that this species seems to be very characteristic of the ridge vegetation of Borneo and of Eastern Malaya. Another species, *Drimys cyclopum*, is recorded by C. E. Lane-Poole [4, p. 86] as undergrowth at 8,000 ft. on Mt. Obree in Papua.

The preponderance of *Sloanea Langii* in the undergrowth of parts of the Eungella Range corresponds with the abundance of straggling and shrubby forms of *Sloanea australis* in the rain forest of Roberts Plateau, Macpherson Range.

VII. Discussion.

The occurrence on the Eungella Range of the six species of trees hitherto regarded as confined to Southern Queensland is a feature of the plant geography of the State. These six species of trees are enumerated in Section V. of this paper. There is a possibility that further botanical surveys will show that some or all of these species extend further into the gap between the Eungella Range and Fraser Island, which is the present extreme northern limit of these species in Southern Queensland. It is very difficult or impossible to determine whether the species under discussion evolved in the south and extended northwards, or originated in the north and spread southwards. On the assumption that the Australian rain-forest flora is an invasion from Papua and Malaya, the latter hypothesis would appear the more feasible one. The distribution of these six species appears to be explainable to a great extent by climatic factors such as temperature, humidity, and rainfall. In respect to these conditions the rain forests of Southern Queensland and the Eungella Range are similar. Sir J. D. Hooker's studies [1] of plant distribution led him to conclude that tropical species extend into cold regions that are humid and equable further than into dry and excessive ones, and, conversely, that temperate species advance much further into humid and equable tropical regions than into those that are dry and excessive. Whether it is assumed that the six species of trees extended northwards to the Eungella Range or southwards to Southern Queensland, the foregoing conclusions of Hooker indicate that climatic conditions are favourable to either assumption. The existence of a gap of over 400 miles in the known distribution of the six species of trees would appear to be explained to some extent by the fact that, with the exception of the small area around Yeppoon, the rainfall of the area in the gap is decidedly lower than that in the rain-forest areas of Southern Queensland and the Eungella Range. The presence in the rain forest of the Eungella Range of many species of the tropical Queensland rain forest may also be accounted for by the climatic factors emphasised by Hooker. The temperature of the Eungella Range is of a temperate character, owing to its altitude, but its high relative humidity, heavy rainfall, and equable climate would facilitate the growth of tropical rain-forest species.

VIII. Summary.

With the exception of the limited area in the neighbourhood of Yeppoon, the heavy rainfall belt, which includes the Eungella Range, is the only markedly moist region between the rain forests of Southern Queensland and of the Cairns region, in the north. The rain-forest flora of the Eungella Range contains constituents of both the southern and northern rain forests of the State. The species constitution of the rain forest of the Eungella Range has evidently been influenced by the intermediate position of the area, its heavy rainfall and its elevation. The area contains some species which are identical with or allied to species abounding in mountain areas of Northern New South Wales, Southern and Northern Queensland, Papua, and Malaya.

Acknowledgments.—The writer is indebted to Mr. C. T. White (Government Botanist) for the determination of some of the specimens, to Mr. D. A. Herbert (Queensland University) for the reference to Hooker's work on climate and altitude, and to Mr. A. H. Cole (Forest Surveyor) and his staff for their assistance in the field work. The illustrations of the paper originally appeared in the "Queenslander," and acknowledgment is expressed to Mr. W. J. Buzacott, editor of that journal, for the process blocks.

REFERENCES.

1. Hooker, J. D., "Botany of Antarctic Voyage," III., Flora Tasmaniæ, XVII., 1860.
2. Ball, L. C., Queensland Geol. Survey Pubn. No. 224, p. 27, 1910.
3. White, C. T. and W. D. Francis, Proc. Roy. Soc. Queensland, 37, 165, Pl. IX., 1926.
4. Lane-Poole, C. E., "The Forest Resources of the Territories of Papua and New Guinea," Australian Commonwealth Govt. Pubn., 50, 1925.
5. Maiden, J. H., "Agricultural Gazette of N. S. Wales," 5, 602, 1894.
6. Gibbs, L. S., "Journal of Botany," 55, 297, 1917.
7. Stapf, O., Trans. Linnean Soc. London, 2nd Series, Botany, IV., 2, pp. 101, 128, 1894.

APPENDIX.

List of Plants Collected on the Eungella Range.

Fl. indicates flowering specimens; im fl., immature flowering specimens; fr., fruiting specimens; im. fr., immature fruiting specimens.

Cyatheaçeæ.—Alsophila Rebeccæ F.v.M.
A. Leichhardtiana F.v.M.

Polypodiaceæ.—Dryopteris truncata O. Ktze.
Arthropteris tenella J. Sm.
Nephrolepis cordifolia Presl.
Davallia pyxidata Cav.
Asplenium nidus Linn.
A. adiantoides C. Christens.
Blechnum cartilagineum Sw. var. tropicum Bail.
Adiantum formosum R. Br.
Polypodium Brownii Wikstr.
P. pustulatum Forst.
Cyclophorus serpens C. Christens.
C. confluens C. Christens.
Platycerium bifurcatum C. Christens.

Marattiaceæ.—Marattia fraxinea Sm.

Pandanaceæ.—Freycinetia excelsa F.v.M. (fl.).

Gramineæ.—Oplismenus compositus Beauv.

Palmæ.—Calamus australis Mart.
Archontophœnix Cunninghamii Wend. & Drude.

Liliaceæ.—Dianella cærulea Sims (fl.).
Cordyline Murchisoniæ F.v.M.
Rhipogonum album R. Br.

Dioscoriaceæ.—Dioscorea transversa R.Br. (im. fl. & im. fr.).

Orchidaceæ. — Dendrobium gracilicaule F.v.M.

Piperaceæ.—Piper Novæ-Hollandiæ Miq.
Peperomia reflexa A. Dietr.

Balanopsidaceæ.—Balanops australiana F.v.M. (fr.).

Ulmaceæ.—Trema aspera Blume (fl.).
Aphananthe philippinensis Planch.

Moraceæ.—Malaisia tortuosa Blanco.
Ficus Cunninghamii Miq.
Ficus stephanocarpa F.v.M. (?).
Ficus stenocarpa F.v.M.

Urticaceæ.—Boehmeria nivea Hook. & Arn. (im. fl.).
Pipturus argenteus Wedd. (fl.).

Proteaceæ.—Helicia glabriflora F.v.M.
Kermadecia Bleasdalii B. & H.

Loranthaceæ. — Loranthus dictyophlebus F.v.M.
Notothixos subaureus Benth. (fl.).

Amarantaceæ.—Deeringia altissima F.v.M. (im. fl.).

Menispermaceæ.—Legnephora Moorei Miers.

Magnoliaceæ.—Drimys dipetala R.Br. (fl.).

Anonaceæ.—Melodorum Leichhardtii Benth.
Eupomatia laurina R.Br.

Monimiaceæ.—Mollinedia subternata Bail. (fr.).
Kibara macrophylla Benth.
Palmeria scandens F.v.M.

Lauraceæ.—Cinnamomum Tamala Th. Nees.
Litsea dealbata Nees (fl.).
Cryptocarya Murrayi F.v.M.
Cryptocarya triplinervis R.Br. (im. fl.).
Cryptocarya hypospodia F.v.M.
Cryptocarya glaucescens R.Br. (?).
Endiandra discolor Benth.
Endiandra longipedicellata W. &. F.

Saxifragaceæ.—Abrophyllum ornans Hook. f.

Pittosporaceæ.—Pittosporum venulosum F.v.M. (fl.).
Hymenosporum flavum F.v.M. (fl.).

Cunoniaceæ.—Ackama Muelleri Benth.

Leguminosæ.—Albizzia procera Benth.
Mezoneurum Scortechinii F.v.M.
Lonchocarpus Blackii Benth.

Rutaceæ.—Pleiococca Wilcoxiana F.v.M.
Zanthoxylum brachyacanthum F.v.M.
Flindersia Schottiana F.v.M.
Acronychia lævis Forst.

Burseraceæ.—Protium australasicum T. A. Sprague.

Meliaceæ.—Cedrela Toona Roxb. var. australis C. DC.
Synoum glandulosum A. Juss (fr.).

Polygalaceæ.—Xanthophyllum Macintyrii F.v.M. (fr.).

Euphorbiaceæ. — Glochidion Ferdinandi Muell Arg. (fr.).
Claoxylon angustifolium Muell. Arg. (fr.).
Mallotus philippinensis Muell. Arg.
Mallotus angustifolius Benth (fr.).
Baloghia lucida Endl. (im. fr.).
Homalanthus populifolius A. Grah. (fr.).

Anacardiaceæ.—Euroschinus falcatus Hook. f.

Sapindaceæ.—Guioa semiglauca Radlk.
Cupaniopsis serrata Radlk.
Sarcopteryx stipitata Radlk. (fl.).
Jagera pseudorhus Radlk.
Arytera Lautereriana Radlk.

Vitaceæ.—Vitis nitens F.v.M.
Vitis oblonga Benth.
Vitis hypoglauca F.v.M.

Elæocarpaceæ.—Elæocarpus ruminatus F.v.M.
Elæocarpus foveolatus F.v.M. (fr.).
Elæocarpus sericopetalus F.v.M.
Sloanea Woollsii F.v.M.
Sloanea Langii F.v.M.

Sterculiaceæ.—Tarrietia argyrodendron var. trifoliolata.
Tarrietia actinophylla Bail.

Dilleniaceæ.—Hibbertia volubilis Andr.

Elæagnaceæ.—Elæagnus latifolia Linn.

Myrtaceæ.—Rhodamnia trinerva Blume (fl.).
Eugenia hemilampra F.v.M. (fr.).
Eugenia macoorai Bail.

Araliaceæ.—Hedera australiana F.v.M.
Panax cephalobotrys F.v.M.

Cornaceæ.—Marlea vitiensis Benth.

Myrsinaceæ.—Ardisia brevipedata F.v.M.
Ardisia pseudojambosa F.v.M.
Embelia australiana Benth. & Hook.

Ebenaceæ.—Diospyros australis R.Br. (im. fl.).
Diospyros pentamera F.v.M. & Woolls.
Maba fasciculosa F.v.M.

Symplocaceæ.—Symplocos spicata Roxb. (im. fr.).

Apocynaceæ.—Chilocarpus australis F.v.M.
Alyxia ruscifolia R.Br.
Parsonsia ventricosa F.v.M. (fr.).
Parsonsia velutina R.Br.
Lysonsia reticulata F.v.M. (fl.).

Asclepiadaceæ.—Marsdenia rostrata R.Br. (fl.).

Borraginaceæ.—Ehretia pilosula F.v.M.
Tournefortia sarmentosa Lam. (fr.).

Verbenaceæ.—Gmelina Leichhardtii F.v.M.

Solanaceæ.—Solanum verbascifolium Ait. (fl.).
Solanum campanulatum R.Br.
Solanum viride R.Br. (fl.).

Bignoniaceæ.—Tecoma jasminoides Lindl. (fl.).
Tecoma australis R.Br.

Gesneraceæ.—Bæa hygroscopica F.v.M.

Rubiaceæ.—Randia chartacea F.v.M.
Psychotria loniceroides Sieb.
Morinda jasminoides A. Cunn. (fl.).
Coelospermum paniculatum F.v.M.

Goodeniaceæ.—Scævola enantophylla F.v.M. (fl.).

Compositæ.—Conyza viscidula Wall (fl.).

Nutritional Exchange between Lianas and Trees.

By D. A. Herbert, M.Sc., Department of Biology,
University of Queensland.

Plate XV.

(*Read before the Royal Society of Queensland, 31st October, 1927.*)

Natural unions between the branches of different individual trees of the same species are somewhat rare, and those between trees of different species are of still less frequent occurrence. Such cases as those of the mistletoes, the sandalwood, and such parasites which habitually form natural unions with plants belonging to other families, must of course be excluded. Adhesion and cohesion of branches have been reported on various occasions in the eastern States of Australia; but in a number of instances one tree has grown in the hollow trunk or branch of another, rooting in the detritus of the pipe and forming no organic union. Such cases are by no means infrequent.

In 1886 the late A. Norton [1] drew the attention of members of the Royal Society of Queensland to the curious behaviour of a stump of Moreton Bay Ash (*Eucalyptus tessellaris*) in the Gladstone district. This remarkable stump had no leaves or branches, and had continued living for from fifteen to eighteen years. Mr. Norton described its appearance as that of a stump which had been left standing when the upper portion of the tree had been snapped off by a strong wind. Its height was 9 ft. 3 in., and its circumference 4 ft. 6 in. No investigation was made of the cause of this remarkable prolongation of life in the absence of leaves, but Dr. (then Mr.) A. J. Turner suggested an inosculation of the roots of the stump with those of neighbouring trees. Dr. Joseph Bancroft, in the same discussion, referred to a spotted gum which, its natural attachment to the ground being severed, had maintained its life by intimate coalescence with the tissues of the branches of two neighbouring trees into which it had fallen. A. D. Hardy [2] records the case of two trees of *Eucalyptus rostrata* 8 ft. apart, joined by a cable root. One of these trees is considered to have been originally a sucker of the other. There is a possibility that this stump was joined to its parent tree in such a way, but from Canada comes interesting support to Dr. Turner's suggestion. Dallimore [3] publishes some observations by C. C. Pemberton, of British Columbia, accompanied by photographs, which prove pretty conclusively that similar stumps of Douglas fir and *Abies grandis* have natural root grafts with other trees. Stumps which have healed over without producing leafy branches continue to live until their neighbouring tree is cut down, when they die.

Cohesion of roots is often seen when a tree is uprooted. Fusion of stems and branches is, however, more easily observed, and Maiden [4] in 1904 gathered some data on natural grafts, and again drew attention to them in his "Forest Flora of New South Wales," in 1917, and [5] in the "Critical Revision of the Genus Eucalyptus" [6] in 1921. In the case of a union between *Eucalyptus hæmastoma* and *E. capitellata,* some of the red colouring matter of the former was found in the fibres of the pale timber of the latter, with which they were in juxtaposition. J. W. Audas [7] in 1911 reported the fusing of a yellow box (*E. melliodora*) with a grey box (*E. hemiphloia* var. *microcarpa*). Hardy (l.c.) figures cohesion of the branches of *E. rostrata,* and describes a composite growth where *E. obliqua* and *E. viminalis* are fused at the base.

Unions of this nature are for the most part between closely related species. Fusions between widely separated forms seem to be unknown, except for a few cases such as that cited by Masters, where a branch of *Sambucus* contracted a firm adhesion with that of *Sophora.* The observations recorded in this paper show, however, that adhesion between unrelated plants often does take place, and that a certain amount of transference of food material from one to the other results from the process.

It was noticed that in the rain forest of Tambourine there occasionally occurred small oval pieces of dead wood like large date-stones stuck to tree trunks. These were obviously no part of the tree to which they were adherent, though they were closely associated with it and could usually only be removed by pulling off a flake of bark as well. There was no union between xylem and xylem. The foreign chip was separated from the living wood by healthy and normal bark. The opinion formed was that these pieces of dead wood were the remains of lianas which had formerly been entwined round the trees and which had died, decayed, and left these oval woody buttons. The well preserved state of the residuals was almost as remarkable as their very definite shape, and there must have been some very good reason for it. A section showed that the bark on the inner side of the chips was still intact and that the cortical parenchyma was fused with that of the bark of the tree. That of the chip was, of course, dead, but its structure was quite well preserved. No tongue of invading tissue penetrated the bark of the tree, but the two sets of parenchyma were in such close contact that food material could readily be transferred by osmosis from one to the other. That such a transfer can be effected is proved by some of the cases already quoted.

The Tambourine Mountain material was too scanty for a general conclusion as to the transference of food from liana to host. No definite proof could be claimed from the examination of two specimens. During August, however, a fortnight was spent in the rain forest on Dunk Island, North Queensland, and a special search commenced for further evidence on the subject. This was soon forthcoming. The woody buttons were found in great numbers, and were no rarity, and the earlier stages of their formation were found as well. These are well shown in the photograph (Plate XV., A., B., C.). A liana wrapped round a living stem dies and commences to decay. Gradually all disappears except a small section a few inches long. This section, when rubbed with the fingers, crumbles away, leaving only the characteristic oval piece of wood firmly adhering to the living bark. In nearly every case this is all that is found; it is not often that the rotten piece of liana is seen. The transition stages are shown in the photograph at A, B, and C.

The size of the wooden button varies; the largest collected was 5¾ in. long, 2 in. wide, and ¾ in. thick. Others ranged in size down to mere splinters. In each case examined, however, the adhesion between parenchyma and parenchyma was quite definite. It was, of course, impossible to identify the liana; there was not enough material in the fragment of undecayed wood for a decision, though it was more than likely that in some cases it was *Entada scandens,* the matchbox bean. The living tree could, however, be classified, and it was found that the range of species with these curious adherent objects was very large. One monocotyledon, *Archontophœnix Alexandræ,* a palm, was included in the list, and almost any of the woody dicotyledonous members of the rain forest and monsoon forest seemed capable of forming such attachments. The case of the palm is of special interest, constituting as it does the first record of a graft between the stem of a monocotyledon and that of a dicotyledon. (Parasitic attachments such as those of *Cassytha* with monocotyledons are not counted). There was, of course, no vascular continuity, but the adhesion of the parenchyma of the two and the transference of material is undoubted.

The structure of the buttons is rather peculiar. Many of them closely resemble a date stone in shape, though differing in size and colour. The groove is on the side remote from the tree and represents the pith of the liana. In none of the specimens discovered did the button represent more than half of the cross section of the lianoid stem; in nearly all cases it was less. Its long axis always corresponded with the axis of the stem of which it was residual. Some of the buttons, especially those in which the rest of the wood had only recently decayed, were partly encrusted with the black wefted hyphæ of a septate fungus, which was possibly one of the Polyporaceæ, though no fructifications were found. In all cases this fungus was found creeping over the under-side of the button and spreading on to the bark of the living tree. At first sight this looked like an appressorium, but in section it was found that the button was not much penetrated except on its outer layers where the other wood had decayed away. The cementing hyphæ were not the agents holding it to the bark of the tree. The conclusion that must be arrived at is that the fusion of the parenchyma of tree and liana, rendered possible by their mutual pressure, had resulted in the transfer of material by osmosis. In the aureole of transfusion the changed chemical constitution of the lianoid stem was sufficient to preserve the wood and bark from the attacks of the dry-rot fungus for some considerable time after the rest of the vine had decayed. It would naturally be expected that the osmotic diffusion would be more favoured in the direction of the longitudinal axis of the stem than in that of the transverse, and that therefore the button would tend to be oval in outline. The exchange can hardly be great, but is sufficient to cause a difference in a few cubic centimetres of liana tissue nearest the point of adhesion.

In such a case of nutritional exchange, the tree stem should show similar change, and the young stem of a liana was found with a large piece of wood adhered to it (Plate XV., D); the case being similar to that of the residual pieces of liana on trees. Only one specimen was found, but it indicates that there is a flow from liana to tree as well as from tree to liana.

SUMMARY.

Small bean-shaped pieces of dead wood found adhering to the trunks of rain-forest trees in North and South Queensland were found to be the remains of lianas which had died and rotted away. It was found that the cortex of the liana had fused with that of the tree, and that the wood and bark of the former had been preserved adjacent to the junction, whereas the rest had succumbed to the attack of a dry-rot fungus. It is concluded that the relative immunity of the woody button from attack was due to the presence of substances obtained by diffusion from the tree. The reverse was where a fragment of a dead tree trunk had been preserved near a junction with a living liana. A case of a graft between the stem of a dicotyledonous vine and that of a monocotyledon (*Archontophœnix Alexandræ*) was also found; as in the other cases there was no vascular connection, but such an occurrence seems to be the first on record.

LITERATURE.

1. NORTON, A.—Proc. Roy. Soc. Q., III., 39, 1886.

2. HARDY, A. D.—Teratological Notes, Part 2; Proc. Roy. Soc. Vict., XXIX. (N.S.), Part 2, 165-172, 1917.

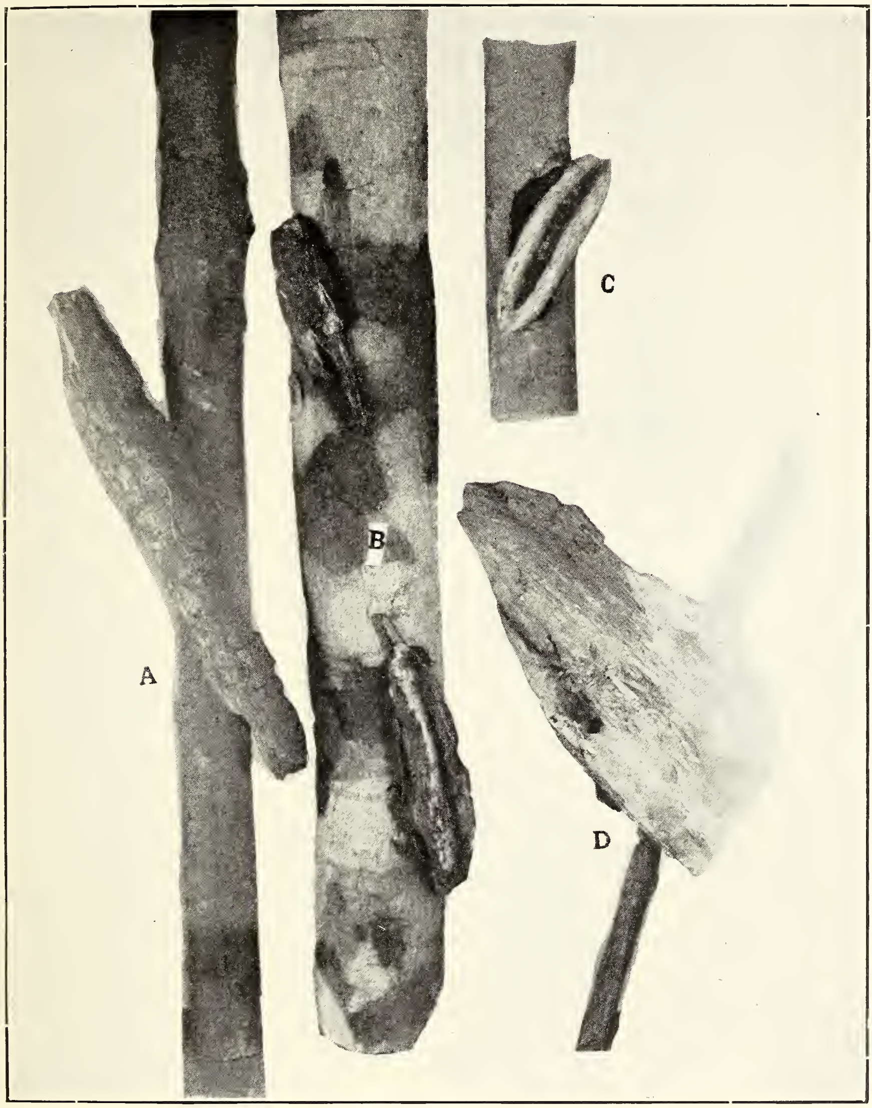
3. DALLIMORE, W.—Natural Grafting of Branches and Roots, Kew Bulletin, 303-306, 1917.

4. MAIDEN, J. H.—Some Natural Grafts between Indigenous Trees, Journ. Roy. Soc. N.S.W., XXXVIII., 36-40, 1904.

5. MAIDEN, J. H.—On Some Natural Grafts between Indigenous Trees, Forest Flora of N.S.W., VI., 79-82 and 287, 1917.

6. MAIDEN, J. H.—Natural Grafts, Critical Revision of the Genus Eucalyptus, V., Part 9, 279-281, 1921.

7. AUDAS, J. W.—Victorian Naturalist, XXVII., 207, 1907.



Natural Grafts between Lianas and Trees.

PLATE XV.

(A) Rotten piece of liana attached to a living stem.

(B) A section of liana which has rotted away, leaving two of the bean-like pieces of wood attached to a living stem.

(C) A characteristic woody residual; the black substance is fungal mycelium.

(D) A thin stem of a liana with the remains of a small tree trunk fused to it. The rest of the tree has decayed, leaving a relatively round piece of wood in contact with the liana.

All half natural size.

Face page 118.]

Revisional Notes on Robber Flies of the Genus *Stenopogon* (Diptera; Asilidae).

By G. H. Hardy,

Walter and Eliza Hall Fellow in Economic Biology, Queensland University, Brisbane.

(*Read before the Royal Society of Queensland, 28th November, 1927.*)

The Australian species of the genus *Stenopogon* are remarkably alike in shape, colour, and general structure; therefore there are few characters available for the ready determination of various described forms, most of which have had their names placed as synonyms of *S. elongatus* Macquart.

The genus was first revised by Ricardo, who recognised only two species, *elongatus* Macquart and *nicoteles* Walker, whereas White subsequently permitted three, the third being the same as that upon which *elongatus* was first established. Macquart's description reads to the effect that the two first pair of femora are red, the anterior ones black basally, whilst the posterior femora are black with red below at the apex. White's description is identical except that he does not refer to the red spot that occurs on the female at the apex of the posterior femora, usually confined to the underside. Both Macquart and White omit the very small black area at the base of the intermediate femora, and indeed White states that this segment is entirely red.

Macquart added two varieties under *elongatus,* both from Tasmania, one having entirely black femora and is undoubtedly that described later by Bigot as *fraternus,* the second being *lanatus* Walker in which all the femora are marked black and red, the intermediate ones being almost entirely red as in the typical *elongatus.* The latter one, *lanatus,* is undoubtedly the form that White mistook for the typical *elongatus,* for he added a description of *fraternus* as a variety and made the original *elongatus* his *flavipennis.*

Dasypogon digentia, and *D. agave* Walker, are distinct species, as also probably is *D. thalpius* Walker, all from Western Australia. The last mentioned is very close to *flavipennis* White, and is only known to me from the female, in consequence of which I have not been able to fully establish its specific identity, whilst those specimens from Queensland that agree with the description of the two first-mentioned may possibly not belong there but it is considered expedient to retain them as here placed until the males are known from the type locality.

Three undescribed species are known, only one of which is included below. The other two are represented by old specimens and are notable on account of the genital characters of the male. One has what appears to be a very short dorsal plate, but closer inspection shows a thin prolongation almost hidden amongst the other parts; the other has an extraordinarily large dorsal plate that extends as far as does the prolongation on that of *nicoteles* and *fraternus*.

The purpose of the present paper is to record the above disentanglement of the identities of early described species. The genital characters, upon which much of this study depends, have not been advanced sufficiently to warrant a fuller account, and some years must pass before the necessary material can be collected for the purpose of finishing these studies. In the meanwhile, specimens are being named in collections in conformity with the plan here adopted, those in various collections in Queensland and in that of the South Australian Museum having already been suitably labelled.

By aid of the following key most of the species will be readily recognised on the characters of the male, but reference to leg characters will usually enable the females to be recognised even if the male is unknown.

1. Moustache almost entirely black; there are some silvery white hairs easily detectable below. All femora black. Male genitalia with a downwardly curved prolongation of the dorsal plate .. .. *nicoteles* Walker.
   Moustache conspicuously yellow, usually entirely so .. .. 2.
2. Dorsal plate with a downwardly curved prolongation. All femora black. Face often with black hairs just at the base of the antennæ. Last two segments on the female abdomen sometimes reddish .. *fraternum* Bigot.
   Dorsal plate simple; without prolongation .. .. 3.
3. Dorsal plate emarginate at the apex. Face with black hair above and on each side of the otherwise yellow moustache. All femora with the apical half red, basal half black .. .. *emarginatus* n.sp.
   Dorsal plate rounded at the apex. Face always with hair entirely yellow, at most a few black ones at the base of the antennæ .. .. 4.
4. Posterior femora, as well as the anterior and intermediate ones, apically red and basally black .. .. *lanatus* Walker.
   Posterior femora entirely black, or rarely a little red at the extreme apex usually confined to the lower side .. .. 5.
5. Intermediate femora almost entirely red, black only at the extreme base; anterior femora red apically .. .. *flavipennis* White.
   Intermediate femora mainly or entirely black .. .. 6.
6. Anterior and intermediate femora red only at the extreme apex, the red being separated by a very defined straight line .. .. *digentia* Walker.
   Anterior and intermediate femora entirely black .. .. .. *agave* Walker.

STENOPOGON NICOTELES Walker.

Dasypogon nicoteles Walker 1849, p. 320. *Stenopogon nicoteles* Ricardo 1912, p. 157.

Hab.—Western Australia; Perth one male, 1911-2.

STENOPOGON FRATERNUM Bigot.

Dasypogon elongatus var. (first) Macquart, suppl. 2, 1847, p. 34. *Stenopogon elongatus var.* White, 1916, p. 164. *Stenopogon elongatus* Hardy, 1927, p. 309, fig. 3. *Stenopogon fraternum* Bigot, 1878, p. 421.

This is the first so-called variety of *elongatus* mentioned by Macquart and also White's variety; the locality for both is Tasmania, which leaves little doubt concerning this identification. It occurs as far north as Sydney and so would appear to be that form upon which Bigot's description was based. Bigot mentions the hair at the base of the antennæ is black, which is taken to mean on the face and front, thus indicating the present species rather than *agave*. Judging from genital characters, this species appears to represent, on the eastern side of Australia, a type that is represented on the western side by *S. nicoteles*.

Hab.—Tasmania: Hobart, Bream Creek, Wynyard, January and February 1916, 1918, and 1924. New South Wales: Sydney, October, and Blue Mountains, November 1918, 1919, and 1924.

STENOPOGON EMARGINATUS n.sp.

This species conforms to others of the genus in all general characters, but is at once distinguished by the male genitalia which have the dorsal plate truncate and with a very definite emargination at its apical border. Moreover the hairs on the face are black below the antennæ and on the tubercle, where they surround the otherwise yellow moustache. From the base to about two-thirds of their length, all the femora are black, from thence to the apex red.

Hab.—Victoria: Gisborne, 1 male, 11–3–17 (G. Lyell).

STENOPOGON LANATUS Walker.

Dasypogon elongatus var. (second) Macquart, suppl. 2, 1847, p. 34. *Stenopogon elongatus* White, 1916, p. 163, typical form only. *Dasypogon lanatus* Walker 1849, p. 318.

This species is readily distinguished by the intermediate femora being mainly red, in conjunction with the half red half black posterior femora.

Hab.—Tasmania: Wedge Bay (pair in copula), January 1918, Hobart, January 1914, Swansea. South Australia: Murray Bridge and Callington, November 1887 (Tepper); Angas Plains. Western Australia: Perth, November 1912; Capel River.

STENOPOGON FLAVIPENNIS White.

Dasypogon elongatus Macquart, suppl. 1, 1847, p. 66, Pl. vii., fig. 6. *Stenopogon elongatus* Ricardo 1912, p. 155, part only (name preoccupied). *Stenopogon flavipennis* White 1917, p. 79.

Asilus elongatus Meigen, was placed under *Stenopogon* by Loew 1847, hence Macquart's name is preoccupied.

The species is recognised by the posterior femora being entirely black, or almost so, in conjunction with the intermediate femora being almost entirely red. The red at the apex of the posterior femora is very inconspicuous, apparently only on the female and usually confined to a spot on the underside.

Hab.—New South Wales: Blackheath and Katoomba, November 1912 and 1919.

STENOPOGON THALPIUS Walker.

Dasypogon thalpius Walker, 1849, p. 317.

This species is very close to if not identical with *S. flavipennis* White. It is only known to me from the female, three specimens of which sex differ in the entire absence of the red at the apex of the posterior femora, and in the larger amount of black at the base of the intermediate pair. It is considered better to keep these names distinct rather than use Walker's for the eastern form with the possibility of having to revert later to the name given by White.

Hab.—Western Australia: Perth, November 1912, three females.

STENOPOGON DIGENTIA Walker.

Dasypogon digentia Walker, 1849, p. 316. *Dasypogon flavifacies* Macquart, suppl. 4, 1850, p. 64, Pl. vi., fig. 6.

In this species the anterior and intermediate femora are red only at the extreme apex, and the very defined line between the colours is remarkably straight. I have not seen it from Western Australia, but Queensland specimens conform to the described characters. Macquart's record from Tasmania is evidently erroneous, as only two species occur in that island.

Hab.—Queensland: Brisbane, September 1921, October 1927.

STENOPOGON AGAVE Walker.

Dasypogon agave Walker, 1849, p. 317.

The male is not known to me from Western Australia, which is Walker's locality, but the female bears a certain distinctive appearance that suggests the Queensland forms possibly do not belong to it; I have, however, not been able to find any characters to separate them other than size. South Australian specimens are of the same form as those of Queensland.

Considerable difficulty will be found in separating the females from those of *S. fraternum,* and I have been unable to find any reliable characters whereby this may be done. The range of the species will help to a certain extent, but they overlap in the Blue Mountains at least. In *fraternum* there are a few black hairs on the face just below the antennæ and are rarely missing, whereas they are rarely present on *agave*. Also there is a marked tendency in *fraternum* from Tasmania to have the last two segments of the abdomen reddish, but this does not appear on those from New South Wales.

Hab.—Western Australia: Hamel (without further data), two females in the Queensland Museum. Queensland: Bunya Mountains, December 1925, Brisbane, September and October 1924 and 1927. National Park, December 1921. New South Wales: Blackheath, November 1919. South Australia: Murray River, Lamaroo, and Callington, November 1887 (Tepper); between Karoomba and Peebing.

LITERATURE REFERRED TO.

MACQUART, 1847–1850.—Diptères exotiques nouveaux ou peu connus. suppl. 1, 2, and 4.

WALKER, 1849.—List of the Dipterous Insects in the British Museum. Vol. 2.

BIGOT, 1878.—Ann. Ent. Soc., France, viii.

RICARDO, 1912.—Ann. Mag. Nat. Hist. (8) ix.

WHITE, 1916 and 1917.—Proc. Roy. Soc. Tasmania for the years 1916 and 1917.

HARDY, 1926.—Proc. Lin. Soc., N.S. Wales, li.

The Royal Society of Queensland.

Report of Council for 1926.

To the Members of the Royal Society of Queensland.

Your Council has pleasure in submitting its Report for the year 1926.

Sixteen original papers were read and discussed before the Society and published during the year. One meeting of a popular character was held. On this occasion Mr. E. Ballard, B.A., delivered a lecture on "A Journey up the Markham Valley, New Guinea."

The Council wishes to acknowledge generous subsidies amounting to £205 from the Queensland Government towards the cost of printing the Proceedings of the Society. Appreciative acknowledgment is also expressed to the University of Queensland for housing the library and providing accommodation for meetings.

The membership roll consists of seven corresponding members, six life members, 155 ordinary members, and six associates. During the year eight new members and one associate were elected. One corresponding member and two life members died.

The deaths of the Honourable A. J. Thynne (a trustee), Mr. Chas. Hedley (corresponding member), Mr. R. H. Roe (life member), and Mr. W. Weedon (life member) are reported with regret.

There were ten meetings of the Council. The attendance was as follows:—E. W. Bick 9, J. V. Duhig 8, W. D. Francis 9, C. D. Gillies 5, E. J. Goddard 4, R. W. Hawken 5, D. A. Herbert 7, H. A. Longman 7, E. O. Marks 10, H. J. Priestley 6, H. C. Richards 5, C. T. White 9.

J. V. DUHIG, President.

W. D. FRANCIS, Hon. Secretary.

THE ROYAL SOCIETY OF QUEENSLAND.

STATEMENT OF RECEIPTS AND EXPENDITURE FOR YEAR ENDED 31st DECEMBER, 1926.

Cr. | Dr.

Receipts.	£	s.	d.	Expenditure.	£	s.	d.
Bank Balance, 31st December, 1925	44	10	7	Government Printer—			
Subscriptions	155	8	0	Volume and Abstract	411	15	0
Government Subsidy—				Stationery Account	3	6	6
1925-1926 Printing Account	70	0	0	State Government Insurance	0	13	0
1926-1927 Printing Account	135	0	0	Hon. Secretary (Postages)	9	0	0
University of Queensland, Extra Reprints	20	18	0	Hon. Librarian (Postages)	3	0	0
A. P. Dodd, Donation Towards Cost of "The Genus *Scelio* Latreille in Australia"	10	0	0	Hon. Treasurer (Postages)	2	0	0
Exchanges	0	6	0	Lanternists (A. N. Falk £1 10s., C. Illidge 10s.)	2	0	0
				Bank Charges	0	10	0
				Exchanges	0	6	10
				Balance in Queensland National Bank, 3rd January, 1927	3	11	3
	£436	2	7		£436	2	7

Examined and found correct.

H. J. PRIESTLEY, Hon. Auditor,
28th February, 1927.

E. W. BICK, Hon. Treasurer.

ANNUAL MEETING.

The Annual Meeting of the Society was held in the Chemistry Lecture Theatre of the University at 8 p.m. on Monday, 4th April, 1927.

The President, Dr. J. V. Duhig, M.B., in the chair.

An apology was received from His Excellency the Lieutenant-Governor, the Honourable W. Lennon.

The minutes of the previous annual meeting were read and confirmed.

The Annual Report and Financial Statement were adopted on the motion of Dr. Bryan, seconded by Mr. Cottrell Dormer.

The following officers were elected for 1927:—

President: Professor E. J. Goddard, B.A., D.Sc.

Vice-Presidents: Dr. J. V. Duhig, M.B. (*ex officio*), Professor T. Parnell, M.A.

Hon. Secretary: Mr. D. A. Herbert, M.Sc.

Hon. Treasurer: Mr. E. W. Bick.

Hon. Auditor: Professor H. J. Priestley, M.A.

Members of Council: Dr. W. H. Bryan, M.C., Professor R. W. Hawken, B.A., M.E., M.Inst. C.E., Dr. E. O. Marks, B.A., B.E., M.D., Professor H. C. Richards, D.Sc., and Mr. C. T. White, F.L.S.

Professor Goddard was inducted to the position of President for 1927.

Mr. J. H. Smith, M.Sc., Dr. G. C. Taylor, M.B., Ch.M., and Misses L. Crawford, M. Fitzgerald, B.Sc., and G. Jones were proposed for ordinary membership.

Mr. G. H. Barker was unanimously elected as an ordinary member.

The retiring President, Dr. J. V. Duhig, delivered his address, entitled "Nutrition." The foods of primitive and civilised man were compared and the effects on the human system outlined. The effect of different diets upon the teeth, the influence of light on nutrition, and the vitamin content of various foodstuffs were among the subjects discussed. Ideal diets for children and adults were suggested.

On the motion of Mr. H. A. Longman, seconded by Professor J. P. Lowson, a vote of thanks was accorded the retiring president for his address.

The Royal Society of Queensland.

ABSTRACT OF PROCEEDINGS, 2ND MAY, 1927.

The ordinary Monthly Meeting of the Society was held in the Geology Lecture Theatre at 8 p.m. on Monday, 2nd May, 1927.

The President, Professor E. J. Goddard, in the chair.

The following were unanimously elected as ordinary members :—J. H Smith, Esq., M.Sc. ; G. C. Taylor, Esq., M.B., Ch.M. ; Miss L. Crawford; Miss M. Fitzgerald, B.Sc. ; and Miss G. Jones.

Mr. George Preston was nominated for ordinary membership.

Professor H. C. Richards exhibited a number of lantern slides of the Great Barrier Reef, illustrating its geology, fauna, and flora. Mr. H. Tryon and the President commented on the subjects.

Mr. H. A. Longman exhibited—(1) the spurs of the common game rooster used as weapons by aboriginal women ; (2) a pointing bone composed of a tibio-tarsus and fibula of an emu and used by aboriginal medicine men. (Aboriginals from mission stations visiting the museum avoid contact with these bones, even after lengthy contact with civilization) ; (3) an aboriginal calvarium (Q.E. 561) from Wynnum—this was an unusually thick and heavy dolichocephalic skull, probably in the process of becoming fossilized. Comments were made by Mr. Tryon, Dr. Marks, and the President. (The first two exhibits shown by Mr. Longman were presented to the museum by the late Mr. Thos. Illidge.)

Dr. Bryan exhibited fossil plants typical of the Ipswich series from the north bank of the Pine River almost opposite the confluence of the North Pine and South Pine Rivers. This forms a new locality record, as the area has been mapped as of Tertiary age. The chief plant present is *Cladophlebis australis.*

Dr. F. W. Whitehouse exhibited a collection of Cambrian trilobites from most of the known Australian localities. Thirteen genera, six of them being new, were represented. Among the new locality records were the following :—(*a*) Species of *Dinesus* and (?) *Notasaphus* from the South Templeton River (N.W. Queensland), in a Middle Cambrian fauna ; (*b*) specimens of *Eodiscus significans* (Eth. fil.) and *Agnostus elkedraensis*, Eth. fil., from the South Templeton River (a new record for Queensland) ; (*c*) a species of *Tsinania* from Caroline Creek, Tasmania. This genus, from the top of the Cambrian, is known otherwise only in China and North America. The following stratigraphical correlations were suggested :— *Upper Cambrian :* Beds of Florentine Valley, Caroline Creek, and Dolodrook ;

High in Middle Cambrian: Beds of Alexandra Station (N.T.), Elkedra (N.T.), Templeton River, and Heathcote ; *Low in Middle Cambrian:* Beds of Yelvertoft (N.W. Queensland), Parara, and near Wirrialpa (South Australia) and Mount Panton (N.T.)

The Secretary communicated a paper by Dr. Thos. L. Bancroft entitled "Preliminary Notes on the Occurrence of Flagellates in the Juice of Certain Queensland Plants." A flagellate was found in the latex of the Asclepiadaceous plants *Sarcostemma australe* and *Hoya australis,* a larger species in *Secomone elliptica,* and a different kind again in *Ficus scabra. Oncopeltus quadriguttatus,* a bug which sucks the juice of the first two plants, had flagellates in its intestines. Microscopic preparations and specimens of the bug were exhibited. Comments were made by Messrs Tryon and Herbert and the President.

ABSTRACT OF PROCEEDINGS, 30TH MAY, 1927.

The ordinary Monthly Meeting of the Society was held in the Geology Lecture Theatre at 8 p.m. on Monday, 30th May, 1927.

The President, Professor E. J. Goddard, in the chair.

Apologies were tendered on behalf of Professor H. C. Richards. Dr. W. H. Bryan, Messrs. G. H. Barker, W. D. Francis, D. A Herbert, and H. Tryon.

The minutes of the previous meeting were read and confirmed.

Mr. Geo. Preston was unanimously elected as a member.

J. R. A. McMillan, Esq., M.Sc., was nominated for ordinary membership.

In the absence of the author, Mr. C. T. White communicated a paper by Mr. W. D. Francis on the "Anatomy of the Australian Bush Nut (*Macadamia ternifolia*)." In addition to the structural features the author outlined the composition of parts of the nut as revealed by micro-chemical tests. A comparative description of the fruits of the other species of the genus was also given. The paper was illustrated by text-figures and photo-micrographs. A discussion took place in which Messrs. Gurney, White, Bick, and the President took part.

Mr. C. T. White also communicated Dr. B. H. Danser's "Revision of the Queensland Species of *Polygona*." This revision shows that up to the present fifteen species of *Polygonum* have been collected in Queensland. Four of these are recorded for the first time in Australia. On the other hand three species—*P. lanigerum* R. Br., *P. subsessile* R. Br., and *P. articulatum* R. Br.—recorded previously as distinct species, are now united with the others.

Mr. H. A. Longman and the President commented on the paper.

Abstract of Proceedings, 27th June, 1927.

The ordinary Monthly Meeting of the Society was held in the Geology Lecture Theatre at 8 p.m. on Monday, 27th June.

The Vice-President, Dr. J. V. Duhig, in the chair, and fifty members and visitors present.

Apologies were tendered on behalf of the President (Professor Goddard) and Mr. C. T. White.

The minutes of the previous meeting were read and confirmed.

Mr. J. R. A. McMillan, M.Sc., was unanimously elected as an ordinary member.

Dr. Duhig announced that His Excellency the Governor, Sir John Goodwin, had consented to become Patron of the Society.

The evening was devoted to the celebration of the Newton Bi-centenary, and the following addresses were given:—

"The Life of Newton," by Mr. Heber A. Longman, F.L.S.;

"Newton as a Mathematician," by Professor H. J. Priestley, M.A.;

"Newton as a Physicist," by Professor T. Parnell, M.A.

A hearty vote of thanks to the lecturers, moved by Professor Hawken, seconded by Professor Scott Fletcher, and supported by Dr. Duhig, was carried by acclamation.

Abstract of Proceedings, 28th July, 1927.

The Ordinary Monthly Meeting of the Society was held in the Geology Lecture Theatre at 8 p.m. on Monday, 28th July, 1927.

The President, Professor E. J. Goddard, in the chair and thirty members present.

An apology for absence was received from Dr. J. V. Duhig.

The minutes of the previous meeting were read and confirmed.

The President referred to the death of Dr. Taylor, a trustee of the Society, and extended sympathy to his relatives.

The President announced that the Society had been represented on a deputation in connection with the proposed open season for native bears, and that there was no need for further action on the matter at this meeting.

Dr. F. W. Whitehouse exhibited a collection of Carboniferous corals from the Lion Creek Limestone, near Stanwell. These included *Syringopora syrinx* Eth. fil., *S. sp. nov.*, **Michelinia sp.*, **Palæosmilia retiformis* (Eth. fil), *Amygdalophyllum inopinatum* (Eth. fil.), *Lithostrotion columnare* (Eth. fil.), and **Petalaxis sp. nov.*, the species marked with an asterisk being new records. He suggested that the coral limestones interbedded in the Lower Carboniferous mudstones at many localities in Eastern Australia were all on much the same horizon, that horizon being the equivalent of D_2 in the European zonal succession.

Dr. W. H. Bryan read a paper by Professor H. C. Richards and himself entitled "Volcanic Mud Balls in the Brisbane Tuff." The paper dealt with a very unusual form of volcanic ejecta in the form of spheroidal pellets of concentric structure found by the authors at Castra on the Tingalpa Creek, twelve miles east-south-east of Brisbane. The only closely similar volcanic product seems to have been formed by the eruption of Taal Volcano in the Philippine Islands in 1911. This was described by Pratt, whose explanation of the spheroids as the result of condensation of the mud balls above the volcano in much the same manner as in the formation of summer hail. Professor Richards added some comments on the paper, which was discussed by Drs. E. O. Marks and F. W. Whitehouse, Messrs. Dormer, Tommerup, Herbert, Denmead, Morwood, Professor Parnell, and the President.

Professor Parnell then took the chair, and a lecture on "Bunchy Top of the Banana," illustrated by specimens and lantern slides, was delivered by Professor Goddard. He dealt with the history of the disease in Australia from its introduction from Fiji to the present, described the symptoms, methods of investigation of the problem, and the treatment. It was pointed out that all members of the genus *Musa* are susceptible, including the wild bananas of North Queensland. A vote of thanks to the lecturer was moved by Mr. Longman and seconded by Professor Richards, but, owing to the lateness of the hour, no discussion of the paper took place.

Abstract of Proceedings, 29th August, 1927.

The Ordinary Monthly Meeting of the Society was held in the Geology Lecture Theatre at 8 p.m. on Monday, 29th August, 1927.

The President, Professor E. J. Goddard, in the chair, and about sixty members and visitors present.

An apology for absence was received from Mr. McMinn.

The minutes of the previous meeting were read and confirmed.

The President called for nominations for three trustees of the Society, and on the motion of Professor H. C. Richards, seconded by Dr. E. O. Marks, it was decided to ask Mr. F. Bennett, Mr. J. B. Henderson, and Dr. A. Jefferis Turner to accept the positions.

Messrs. A. M. Epps and L. Franzen were nominated for ordinary membership of the Society.

Dr. F. W. Whitehouse exhibited (*a*) goniatites, probably belonging to the genus *Eumorphoceras,* from the Rockhampton Series at the 2-mile tunnel on the Many Peaks-Monto Railway. These appear to represent an horizon about the very base of the Upper Carboniferous); and (*b*) rolled Devonian pebbles containing *Spongophyllum halysitoides* from the lower limestone in the carboniferous beds near Mt. Lion (Central Queensland).

Dr. W. H. Bryan exhibited specimens of a non-calcareous oolite from the north bank of the Pine River, about three miles from its mouth.

Professor E. J. Goddard exhibited a live specimen of a new species of *Peripatus* collected on Dunk Island, North Queensland, by Mr. W. Cottrell Dormer during the University biological excursion in the latter part of August.

A lecture entitled "Giants of the Past," illustrated with specimens and lantern slides, was given by Mr. Heber A. Longman, F.L.S., C.M.Z.S. The principal vertebrate fossils found in Queensland deposits were concisely dealt with, prominence being given to the large marsupial cranium from Brigalow, Darling Downs, described as *Euryzygoma dunense,* and to the giant Dinosaur *Rhoetosaurus brownei.* An outline was given of the classification of the many families of Dinosaurs, and the lecturer stated that recent intensive studies of comparative anatomy had greatly enlarged our knowledge of extinct as well as living vertebrates.

A vote of thanks to the lecturer was moved by Dr. E. O. Marks and seconded by Professor H. C. Richards.

Abstract of Proceedings, 26th September, 1927.

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre at 8 p.m. on Monday, 26th September, 1927.

The President, Professor E. J. Goddard, in the chair, and about thirty members present.

Apologies for absence were received from Professor Richards and Mr. Longman.

The minutes of the previous meeting were read and confirmed.

Messrs. A. M. Epps and L. Franzen were elected ordinary members of the Society.

Dr. E. O. Marks exhibited waterworn pebbles of igneous rock from the Mesozoic sandstone at Caloundra. Dr. Bryan and Mr. F. Bennett commented on the exhibit.

A paper on "Plants collected in the Mandated Territory of New Guinea by C. E. Lane-Poole," by Messrs. C. T. White and W. D. Francis was communicated by Mr. C. T. White. He laid on the table Mr. Lane-Poole's Report on the Forest Resources of the Territories of Papua and New Guinea, published by the Commonwealth Government in 1925, which contained the narrative of the expedition and field notes on the specimens collected. Four species were described as new: *Saurauja emarginata* (Dilleniaceæ), *Eurya albiflora* (Ternstroemaceæ), *Mearnsia cordata* (Myrtaceæ), and *Hoya Poolei* (Asclepiadaceæ); and a number of new records were made of the distribution of known species.

Mr. A. K. Denmead, B.Sc., read a paper entitled "A Survey of the Brisbane Schists." This was an account of his investigations of the basal rocks between Tweed Heads and Rockhampton. He divided the rock formations into four series: (1) The greenstone series, largely in evidence near Petrie and Dayboro'; (2) the Bunya series, mica-phyllites, found principally in the area between Brisbane and Dayboro'; (3) the Neranleigh series of greywackes, slates, &c., between Nerang and Beenleigh, and (4) the Fernvale series of jaspers, limestones, serpentines, &c. The trend of the rocks generally, he said, was from north-north-east to south-south-east. He advanced theories as to earth foldings and faults, and suggested that, in point of age, the lower beds were Silurian, passing through the Silurian into Devonian, and possibly through the Devonian into the Carboniferous. The paper was discussed by Dr. Bryan (who also communicated Professor Richards' comments), Drs. Whitehouse and Marks, Messrs. Tryon, Massey, and Bennett.

Abstract of Proceedings, 31st October, 1927.

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre at 8 p.m. on Monday, 31st October, 1927.

The President, Professor E. J. Goddard, in the chair, and about twenty members present.

Apologies for absence were received from Professors Parnell and Richards, Dr. Bryan, and Mr. Longman.

The minutes of the previous meeting were read and confirmed.

Dr. L. Bagster exhibited two blocks of slag showing large crystals, which were probably a silicate of calcium and iron. The specimens had been presented to the Geology Department by Mr. Boyd of Mount Morgan. Comments were made by Messrs. F. Bennett and H. Tryon.

Dr. J. V. Duhig demonstrated the hæmolytic action of the venom of the dorsal spines of the common Stone Fish (*Synanceja horrida*), as a preliminary to a paper to be published later on the venom of this species. He showed three tubes—(1) washed guinea-pig red cells + *Synanceja* venom, sedimented, showing a marked zone of hæmolysis; (2) the same as the first, but shaken to show the hæmoglobin in solution; (3) red cells

+ saline solution showing no hæmolysis. Dr. Duhig also briefly explained the neurotropic action of *Synanceja* venom, and demonstrated the poison sacs *in situ* on a dissected dorsal fin spine. The exhibit was commented on by Mr. F. Bennett and the President.

Mr. E. W. Bick exhibited an egg laid by a cassowary in captivity in the Botanic Gardens. This bird, when first brought to the gardens, had been considered an exceptionally fine specimen of a male by some ornithologists. The President, in commenting on the exhibit, spoke of the relative frequency of occurrence of sex reversal in birds, and suggested the possibility in this instance. Dr. Duhig said that he had a hen at his home which had developed male characters.

Mr. W. D. Francis read a paper entitled, "The Rain-forest Flora of the Eungella Range." The rain-forest flora of the Eungella Range contains constituents of both the Southern and Northern rain-forests of the State. Its species constitution has evidently been influenced by the intermediate position of the area, the heavy rainfall (65 inches), and the elevation. The area contains some species which are identical with or allied to species abounding in mountain areas of Northern New South Wales, Southern and Northern Queensland, Papua, and Malaya. The paper was commented on by Messrs. Bennett, Bick, Tryon, Simmonds, Herbert, and the President.

Mr. D. A. Herbert read a paper on "Nutritional Exchange between Lianas and Trees." Small oval pieces of wood attached to rain-forest trees were found to be fused to the trunks. It was shown that these were the remains of woody vines which had rotted, leaving only small residual pieces of wood. It was contended that this was the result of the rotting away of other parts of the vine, the fungus not attacking the woody button so readily because of the presence of substances derived from the stem with which fusion had taken place. Specimens were exhibited showing stages in the formation of the buttons, one being noteworthy in showing the fusion of a dicotyledonous vine with a palm (*Archontophœnix Alexandræ*). The paper was commented on by Messrs. Tryon and Bennett.

Abstract of Proceedings, 28th November, 1927.

The Ordinary Monthly Meeting of the Society was held in the Geology Lecture Theatre of the University at 8 p.m. on Monday, 28th November, 1927.

The President, Professor E. J. Goddard, in the chair.

The minutes of the previous meeting were read and confirmed.

Dr. O. S. Hirschfeld was nominated for ordinary membership.

Mr. H. A. Longman exhibited (1) a specimen of the fat-tailed pouched mouse, *Sminthopsis crassicaudata,* with the pouch area much enlarged and containing six well-developed pouch-embryos, which had been sent to the Queensland Museum by Mr. F. L. Berney, Barcarolle, Longreach; (2) a skull of *Macropus giganteus* from Torrens Creek, Northern Queensland, with a supernumerary upper incisor; (3) a fragment of a left maxilla of *Diprotodon australis,* containing the second and third molars, which had been found on Urana Run, Collinvale, Bowen district, Northern Queensland, and presented by Mr. A. Garbutt.

Dr. E. O. Marks exhibited a specimen of crystalline slag from Mount Morgan.

Mr. W. D. Francis exhibited a specimen of Australian ebony (from *Maba humilis*) which had been forwarded by Mr. Allen from the Northern Territory.

Dr. Marks, Mr. G. Parker, and the President discussed the exhibits.

Mr. G. H. Hardy read a paper entitled "Revisional Notes on Robber-flies of the genus *Stenopogon* (Diptera; Asilidæ)."

Publications have been received from the following Institutions, Societies, etc., and are hereby gratefully acknowledged.

AFRICA.

ALGERIA—

Société de Géographie et d'Archéologie d'Oran, Oran.

UNION OF SOUTH AFRICA—

Durban Museum, Natal.
South African Museum, Capetown, Cape Province.
Transvaal Museum, Pretoria.
Geological Society of South Africa, Johannesburg.

AMERICA.

ARGENTINE—

Museo de la Plata, Universidad Nacional de la Plata.

BRAZIL—

Instituto Oswaldo Cruz, Rio de Janeiro.
Ministerio de Agricultura, Industria y Commercio, Rio de Janeiro.

CANADA—

Department of Agriculture, Ottawa.
Department of Mines, Ottawa.
Royal Society of Canada, Ottawa.
Royal Astronomical Society of Canada, Toronto.
Royal Canadian Institute, Toronto.
Nova Scotia Institute of Science, Halifax, Nova Scotia.

UNITED STATES OF AMERICA—

Carnegie Institution, Washington.
Library of Congress, Washington.
National Academy of Sciences, Washington.
National Research Council, Washington.
Smithsonian Institution, Washington.
United States Department of Agriculture.
United States Department of Commerce (Bureau of Standards), Washington.
United States Department of the Interior (United States Geological Survey), Washington.
United States National Museum, Washington.
United States Treasury (Public Health Service).
Lawde Observatory, Arizona.
University of California and Scripps Institute, Berkeley, California.
John Hopkins University (Institute of Biological Research), Baltimore.
American Academy of Arts and Sciences, Boston.
Boston Society of Natural History, Boston.
Buffalo Society of Natural Science, Buffalo.
John Crerar Library, Chicago.
Field Museum of Natural History, Chicago.
Lloyd Library, Cincinnati.
Ohio Academy of Science, Columbus.
Ohio State University, Columbus.
Bernice Pauahi Bishop Museum, Honolulu.
Natural History Survey, State of Illinois.
Indiana Academy of Science, Indianopolis.
Cornell University, Ithaca, N.Y.
Cornell University Agricultural Experiment Station
Arnold Arboretum, Jamacia Plain, Penn.
University of Kansas, Lawrence.
Wisconsin Academy of Arts, Science, and Letters, Madison.
Michigan Academy of Arts, Science, and Letters, Michigan.
University of Michigan, Michigan.
Minnesota Geological Survey, Minneapolis.
University of Minnesota, Minneapolis.
New York Academy of Sciences, New York.
American Geographical Society, New York.
American Museum of Natural History, New York.
Bingham Oceanographic Collection, New York.
New York Zoological Society, New York.
Oberlin College, Ohio.
Academy of Natural Sciences, Philadelphia.
American Philosophical Society, Philadelphia.
Portland Society of Natural History.
Rochester Academy of Science, Rochester.
San Diego Society of Natural History, San Diego.
California Academy of Sciences, San Francisco.
Puget Sound Biological Station, Seattle.
Missouri Botanical Garden, St. Louis.
University of Illinois, Urbana.

MEXICO—

Instituto Geologieo de Mexico, Mexico.
Sociedad Cientifica, "Antonio Alzate," Mexico.
Observatorio Meteorologico Central, Tacaibaya D.F., Mexico.
Secretario de Agricultura y fomento, Mexico.

ASIA.

CEYLON—
Colombo Museum, Colombo.

INDIA—
Agricultural Research Institute, Pusa.
Government of India—
Department of Agriculture.
Geological Survey.
Superintendent, Government Printing.
Punjab University.
Indian Academy of Science.

JAPAN—
Imperial University, Kyoto.
Imperial University, Tokyo.
National Research Council of Japan, Toyko.

JAVA—
Koninklijke Naturkundige, Batavia.
Departement van Landbouw, Buitenzorg.

PHILIPPINE ISLANDS—
Bureau of Science, Manila.
College of Agriculture, University of the Philippines, Manila.

AUSTRALIA AND NEW ZEALAND.

COMMONWEALTH—
Australian Commonwealth Engineering Standards Association, Melbourne.
Commonwealth Department of Health, Melbourne.
Commonwealth Institute of Science and Industry, Melbourne.

QUEENSLAND—
Department of Agriculture, Brisbane.
Department of Mines, Brisbane.
Queensland Geological Survey, Brisbane.
Queensland Museum, Brisbane.
Queensland Naturalists' Club, Brisbane.
Royal Geographical Society of Australasia (Queensland), Brisbane.
State Statistician, Brisbane.

NEW SOUTH WALES—
Australasian Association for the Advancement of Science, Sydney.
Department of Agriculture, N.S.W.
Botanic Gardens, Sydney.
Geological Survey of N.S.W., Sydney.
Public Library, Sydney.
Linnean Society of N.S.W., Sydney.
Australian Museum, Sydney.
Royal Society of New South Wales, Sydney.
Naturalists' Society of N.S.W., Sydney.
University of Sydney.

VICTORIA—
Bureau of Census and Statistics, Melbourne.
Royal Society of Victoria, Melbourne.
Field Naturalists' Club, Melbourne.
Department of Agriculture, Melbourne.
Department of Mines, Melbourne.
Australasian Institute of Mining and Metallurgy, Melbourne.
Australian Veterinary Association, Melbourne.

TASMANIA—
Royal Society of Tasmania, Hobart.
Field Naturalists' Club, Hobart, Tasmania.
Geological Survey of Tasmania.

SOUTH AUSTRALIA—
Royal Society of South Australia, Adelaide.
Royal Geographical Society of S.A., Adel.
National Museum of South Australia, Adel.
Geological Survey of S. Australia, Adel.
Public Library, Museum, and Art Gallery, Adel.
University of Adelaide.

WESTERN AUSTRALIA—
Royal Society of Western Australia, Perth.
Geological Survey of Western Australia, Perth.

NEW ZEALAND—
Auckland Institute, Auckland.
New Zealand Board of Science and Art.
Dominion Laboratory, Wellington.
Geological Survey of New Zealand.
New Zealand Institute, Wellington.
Dominion Museum, Wellington.

EUROPE.

League of Nations, Geneva.

AUSTRIA—
Natural History Museum, Vienna.

BELGIUM—
Academie Royale, Bruxelles.
Société Royale de Botanique de Belgique, Bruxelles.
Société Royale Zoologique de Belgique, Bruxelles.

CZECHO-SLOVAKIA—
Spolecnosti Entomologické, Prague.
Plant Physiological Laboratory, Charles University, Prague.

DENMARK—
The University, Copenhagen.

FRANCE—
Société Botanique de France, Paris.
Société Geologique et Mineralogique de Bretagne, Rennes.
Société des Sciences Naturelles de l'Onest, Nantes.
Musée d'Histoire Naturelle, Paris.
L'Observatoire de Paris.
Station Zoologique de Cette (Université de Montpelier), Cette.
Société de Geographie de Rochefort.
Observations Météorologiques de Mont Blanc.
Office Scientifique des Pêches Maritimes.

GERMANY—
- Naturwissenschaftlichen Verein, Bremen.
- Bibliothek der B., Akademie der Wissenschaften, Munich.
- Notgemeinschaft der Deutschen Wissenschaft, Berlin.
- Senckenbergischen Bibliothek, Frankfurt, A.M.
- Naturhistorischer Verein der preus Rheinland und Westfalens, Bonn.
- Sachs Akademie der Wissenschaften, Leipzig.
- Deutsche Geologische Gesellschaft, Berlin.
- Zoologischen Staatsinstitut und Zoologischen Museum, Hamburg.
- Gesellschaft für Erdkunde, Berlin.
- Centralblatt für Bakteriologie, Parasitenkunde und Infectionskrankheiten.
- Feddes Repertorium, Berlin.
- Zooloogische Museum, Berlin.
- Institut für Zreltwirtschaft und Seeverkehr, University of Kiel.

GREAT BRITAIN—
- Cambridge Philosophical Society.
- Conchological Society of Great Britain and Ireland.
- Imperial Bureau of Entomology, London.
- Literary and Philosophic Society, Manchester.
- Royal Society of London.
- Royal Botanic Gardens, Kew.
- Royal Colonial Institute, London.
- Royal Society of Edinbugh.
- Botanic Society, Edinburgh.
- Royal Irish Academy.
- British Museum (Natural History).
- Royal Dublin Society.

HOLLAND—
- Technisthe Hoogeschool, Delft.

ITALY—
- Societa Africana d'Italia, Naples.
- Instituto di Bologna.
- Societa Toscana di Scienze Naturali, Pisa.
- Museo Civico, Genova.

POLAND—
- University of Poland.
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PROCEEDINGS

OF THE

ROYAL SOCIETY

OF

QUEENSLAND

FOR 1928.

VOL. XL.

ISSUED 12th MARCH, 1929.

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Vol. XL., No. 1.

Proceedings of the Royal Society of Queensland.

Presidential Address.

By Professor E. J. Goddard, B.A., D.Sc.

(*Delivered before the Royal Society of Queensland, 19th March, 1928.*)

It is my pleasing duty, as President of the Royal Society of Queensland, to record a year of sound scientific activities on the part of the Society. The general nature of those activities is set out in the Annual Report of the Council which has been read to you this evening.

Before referring to general matters which have the interest of the Society, I wish, on behalf of the Royal Society of Queensland, to express appreciation of the association with the Society of such men as the late Professor Liversidge and the late Professor Rennie, both of whom were corresponding members of the Society; and of the services rendered during a long period of years by the late Dr. W. F. Taylor, who acted as a Trustee of the Society. We regret very much the deaths of these gentlemen, and in realising the value of the help which they gave through their association to the Society at a period when science and scientific effort, such as manifested by the Royal Society, was of less value in the eyes of the community than it is at the present time, we offer to their relatives and friends our sincerest sympathy.

There are several matters which, as retiring President, I consider should be mentioned on such an occasion as this in the interests of the Society. The Royal Society of Queensland is dependent for its existence on a membership roll which is far too limited in numbers, and on financial support from the Government of Queensland, which assistance we gratefully acknowledge. As President of the Society, I do feel that there are many members of the community whose professional interests and general outlook on life are scientific or incline in that direction, and who might be expected to throw in their lot with the Society. It is frequently stated that the subjects which constitute the basis of discussions at our ordinary meetings, and which form the substance of our Annual Proceedings, are limited and specialised to an extent that denies interest to many of the class to whom I have alluded. I would like to say, as President of the Society, that this is no fault of the Society itself. Any restriction on the nature of subjects coming before the

Royal Society arises from the restricted interests of the members constituting the Society. The Council would welcome a greater variety of scientific contributions, and would be pleased to welcome to the membership of the Society all those who take a real interest in matters scientific.

There is one other matter in connection with the activities of the Society that calls for specific mention, and that is that the Royal Society not only places no limit on the nature of the scientific contributions placed before it, but is anxious to foster all forms of economic or applied research.

The Council notes with satisfaction the increased and intensified interest being manifested by Commonwealth and State Governments in matters scientific, and while this interest is largely in the direction of scientific research in relation to industry and production, yet it indicates practical sympathy with scientific effort. It is noted with pleasure that the Council for Scientific and Industrial Research is appointing a staff of first-class scientific men to deal with problems of importance to industry and production in all its branches, and in so doing is setting an example by offering emoluments sufficient not only to attract first-class men but to encourage younger men to appreciate that there are better opportunities ahead than has been the case in the past. The Council notes with pleasure the appointment of a Board of Agriculture by the Government of Queensland, and representative of the various bodies concerned in agricultural research within the State, with a view to co-ordinating the activities of these various State bodies *inter se* as well as with the activities of the Council for Scientific and Industrial Research and the Development and Migration Committee. The Royal Society of Queensland, as the oldest scientific body in this State, can view with satisfaction these happenings and developments, for the Royal Society of Queensland has, from its beginning, encouraged interest in scientific research for the sake of science, realising long before any appreciation of science was engendered in the minds of the community, that scientific research lay at the basis of human development.

The Society welcomes the activated interests of Governments in scientific research, and while recognising that there is still a long way to go before industry in general appreciates to the full the dependence of its future efficient development on science, yet faces the future in this respect with optimism. It is hoped that in this march towards advancement younger members of the present and future generations possessing a love or aptitude for science will be attracted to the fields of scientific research. This is one of the great needs in Australia at the present day.

* * * * *

Virus Diseases and their Bearing on the Cell Theory and other Biological Concepts.

I have chosen as the title of my Presidential Address this evening that of "Virus Diseases and their bearing on the Cell Theory and other biological concepts." I do not propose to attempt anything of a monographic nature on virus diseases—such would be premature—but to indicate to you the importance of these diseases and their relation to humanity from an economic and scientific standpoint. Any investigator concerned with researches into virus diseases is constantly being drawn in mind towards many somewhat abstruse and very imperfectly understood fundamental biological problems. Although I do not claim any specific originality in respect of the general subject matter of this address, yet I would say that association with certain investigations into a plant virus disease has for the past few years largely dominated my mental horizon in so far as biology is concerned. I feel that a Presidential Address offers a special opportunity—which should be seized—of presenting some subject which has wider scientific incidence, more constructive value, and greater general interest than a specialised scientific paper which might be expected to find its place in the Proceedings of the Society. To my mind no biological problems have more fundamental scientific significance immediately than those of virus diseases, nor is there any biological problem confronting us to-day which appears to have greater significance in so far as humanity is concerned. We know comparatively little about the problem of living matter ; we have been nurtured with certain ideas that dominate our biological horizon, such as the cell theory, which occupies in the mind of the biologist the position that the atom occupied in the mind of the chemist until comparatively recent years. The atom still constitutes a necessary unit in our mental catalogue for descriptive chemical purposes, but a desire for a more profound understanding of the inorganic world, and the attainment of that philosophic perspective which is synonymous with the term "scientific," compels us to have regard for such ideas as the identity or equation between energy and matter and the quantum theory. In the same way the cell will always remain as a useful working unit in our mental catalogue for descriptive biological purposes, but the tendency to regard such a unit as the ultimate entity in considering problems within the realms of biology must be avoided. The cell theory will remain, but biological ideas will progress.

Virus diseases have a variety of interest. Firstly, their significance from an economic standpoint is being forced on us with increasing stress each succeeding year, and it seems highly probable that gradually the most important of our domesticated plants will yield examples of these insidious maladies. They have their incidence also in the animal kingdom, where numerous diseases have been proved to be due to the presence of an ultra-virus. In so far as plants are concerned, it would not be stigmatised as a gross exaggeration of the present position to prophesy that virus diseases directly and indirectly will ultimately dominate the science of plant pathology. Such a statement need not necessarily be construed as suggesting that something of a catastrophic character has been delivered by Nature ; it simply means that with increased knowledge, not only of natural living objects themselves, and arising out of that, the availability of more subtly devised means and technique, we are enabled in our attempt to diagnose the mysterious ills of plants to get down nearer and nearer to the basic idea concerning the problems of living matter. The ultimate goal will never be reached; we are simply passing milestone after milestone, reaching nearer and nearer to that unattainable goal. New problems will arise as we progress ; what once merited the status of a cause will be relegated to that of effect ; what appears to be a basic idea of to-day becomes merely a further acquisition of knowledge to-morrow. Further, it may well be that, in plant-virus diseases at least, we are viewing the results of a disturbance in the balance of Nature in a way which will be indicated later in this address ; or it may be that we are paying the price for an intensive effort in the direction of plant domestication. Such ideas have arisen in the past, and still continue to arise in the minds of investigators confronted with the problem of virus diseases. The whole matter of plant-virus diseases was considered recently at the Imperial Agricultural Conference, and it was there decided that one of the most important avenues of research meriting attention throughout the British Empire was that of fundamental research into virus diseases.

This may serve to indicate that I have not exaggerated the importance of my subject from an economic standpoint.

Secondly, virus diseases would, according to our present interpretation of their nature and cause, seem to open up a sphere of investigation of intense scientific interest, inasmuch as they lead us directly in our present state of knowledge to an intensive attempt to unravel the mechanism and physiology of the cell.

Thirdly, bound up with what I have mentioned above, is the high possibility that investigations into virus diseases may lend very important help to an understanding of the nature and cause of cancer, as well as unravelling the reasons which lie behind the beneficial effects which are derived in certain cases at the present time by various types of irradiation.

The idea that there were beings of such minute size as to be invisible under the highest powers of the microscope received mention as early as 1674, *i.e.*, over two centuries ago. Even Pasteur, who did so much to throttle the idea of spontaneous generation and secured a firmer and firmer basis in biology for the cell theory by his bacteriological studies, once stated that if the causal organism of rabies could not be seen under the microscope, then it was simply because its dimensions were too small for the limits of visibility of this instrument. As I propose to devote attention this evening, in so far as virus diseases are concerned, to examples drawn from the plant kingdom, I may be permitted to give a brief résumé of the history of plant-virus diseases.

The earliest discovery of a plant-virus disease was made in 1893 by Iwanowski, who showed that a mosaic disease of tobacco was a contagious disease, and that the causal agent could be passed through a filter candle. Later experiments within the next two years corroborated the extreme minuteness of the contagious element, and led to the development of the hypothesis that the contagious element was a *contagium fluidum vivum*. Since that time many other filterable viruses have been discovered, although it has been proved that some of these are no longer to be regarded as true viruses, *i.e.*, ultra-viruses, but represent minute organisms, such as bacteria, etc. Virus diseases are now known to be represented among the diseases affecting such a wide range of plants as tomato, turnip, potato, sweet pea, asters, beans, bananas, beet, cabbage, celery, cucumber, sugar-cane, hop, lettuce, melon, pea, peanut, raspberry, pepper, cineraria, clover, cotton, corn, spinach, soy bean, tobacco, etc. The list is not to be regarded as complete. For a very long time many of these diseases were placed in the category of physiological diseases, but gradually as suspicion of the presence of an ultra-virus was aroused a development of our knowledge of the symptoms led to a systematising of those symptoms which now places us in a position to at once suspect the virus nature of the causal agent in such diseases. One feature common to all virus diseases is their transmissibility from diseased to healthy plants, due to the presence of something which we term a virus or ultra-virus,—perhaps the latter term might be used.

There is one significant feature about virus diseases, and that is the symptoms of the disease in a particular plant may include certain appearances, malformations, etc., which occur in otherwise healthy plants as the result of environmental influence, some due to one particular environmental factor, others to another, and so on. With respect to transmissibility, virus diseases fall into three groups, namely, those in which the disease can be transmitted by inoculation of the juice from a diseased plant into a healthy plant, by grafting or through an insect vector; those in which insects and grafting serve to transmit the disease; and those in which the disease is transmitted by budding or grafting, no insect vector having yet been discovered, and inoculation experiments having failed.

In general, those types of virus disease in which transmission can be effected by inoculation are termed mosaic diseases, but, not only is there no reason for regarding causal agents as falling in a different category to that in which is included the causal agent of other plant-virus diseases, but there are so many points of resemblance between the two groups that, in the present state of our knowledge, we should not stress the importance of our inability to effect the transmission by artificial inoculation. Both groups are systemic diseases, that is to say, all parts of the plant are affected, and further, there is no hope of recovery on the part of the plant when the disease has once appeared. In the case of mosaic diseases the symptoms are fairly uniform, but in the case of non-mosaic types there is a wider variety of symptoms, although, as in the former, the foliage is markedly affected and there is a conspicuous dwarfing of the shoots. In Australia several outstanding examples of virus diseases have called for investigation, and it is pleasing to record that in some cases investigation has resulted in a determination of the nature and mode of transmission of the disease. I refer to tomato wilt and bunchy-top in bananas. The former has been proved to be a virus disease of the non-mosaic type which is transmitted from plant to plant by the insect *Thrips tabaci* ; the second is also a non-mosaic virus disease which is transmitted from plant to plant by the banana aphis, *Pentalonia nigronervosa*.

In the investigation of the latter disease, a very thorough pathological examination which was continued throughout the period of investigation failed to reveal any bacterial or fungal organism which could be regarded in any way as contributing to the cause of the disease, although various investigators previously considered the possibility that some fungus would be associated with the disease. The experiments which proved, or were regarded as proving, the virus nature of this disease, have been repeated many times since, not only here but elsewhere, and it is satisfactory to record that the theory of the virus nature has in every case been substantiated. The association of an insect vector in both these cases was rendered difficult of detection at first in the field, and to some extent this is linked up with the fact that a considerable period elapses after the transfer of infected insects to healthy plants before the symptoms of the disease appear, sixteen to twenty days being required in the case of tomato wilt, twenty-six in the latter case. No doubt this period is spent in the propagation of the virus within the plant, for it must be said that one cannot get away from the idea that the symptoms and development of a virus disease insistently proclaim that the virus substance is capable of propagation. Rather does this appear to be the case than that any developmental phases are passed through within the insect, comparable to the phases of the life-history specifically restricted to the period within the insect in the case of protozoan diseases, such as malaria. While sufficient has been discovered in the case of bunchy-top to enable the framing of recommendations which are proving effective in the direction of controlling and eradicating the disease, there still remains a great deal to be done on the scientific side, especially in view of the fact that the banana plant offers excellent material for the investigation of a virus trouble. Researches are still being conducted, and these embrace such studies as the determination of the life-history of the aphis, the number of generations of aphides through which the virus may persist, the determination of other possible host plants of the aphid, the examination of such plants, other possible vectors of the disease, and the possible relation of other host plants to the infection of the banana, determination of the possible locus or loci of infection in the banana by aphides with special relation to the meristematic tissues. The last-mentioned inquiry is one of extreme interest inasmuch as the phloem of the banana plant is affected by the virus in such a way as to suggest the possibility of throwing light on such problems of disturbed metabolism, growth and reproduction of cells, as occurs in cancerous tissue. Further, the disease, in so far as the tissues of the plant are concerned, is not retrospective, that is to say, non-meristematic tissue developed before the introduction of the virus, is not visibly affected from a structural point of view ; and this leads in the direction of offering opportunities for work on readily accessible material which may throw light on the persistence of the meristematic or embryonic function of cancerous tissue.

Another very suggestive line of inquiry is that of a study of means of preventing the development of the disease when loci of infection are discovered. This opens up an opportunity of testing out the effect of different types of irradiation in a very convenient way. Irradiation in relation to meristematic tissues and cancer problems opens up an alluring field of investigation. It is of interest to record in this connection that the only record that we have of anything approaching the status of observed evidence in support of the now commonly accepted belief that the so-called ultra-viruses are particulate, comes from ultra-microscopic investigations associated with cancer investigation. I hasten to add, however, that the evidence cannot yet be regarded as overwhelmingly convincing. Then arises the advisability of carrying out investigations bearing on the latency of a virus disease, for which again the banana plant offers excellent material. There is more than a suspicion at the present day that banana plants may act as carriers of bunchy-top, that is to say, they remain as apparently healthy plants, serving to distribute the disease either through descendent portions of the plant or through the insect vector. Then there is the important point of the transmission of the disease to other plants of other species, which may throw very important light, not only on the nature of the virus, but more particularly on the origin of the virus or virus particle in the first place.

The inability to detect any visible causal agent was responsible, as we have heard, for the idea that some new type of agent was responsible for the disease, and so arose the idea of a *contagium vivum fluidum*. Opposed to this have been developed other theories which embrace bacterial origin, enzyme origin, protozoan origin, etc., of the causal agent. There are to-day at work in every civilised country investigators concerned with virus diseases, and there is a general concensus of opinion among these workers as a result of intensive study of the development of the symptoms of various virus diseases that not only are we concerned with what we term a virus, but that that virus is also particulate. This interpretation is consistent with the occurrence of filter-passing bacteria and the reasonable suggestion that still smaller bacterial (?) forms might be expected to exist—all this leading to a continuity of serial forms the ultimate members of which would be inadmissible as cellular forms. By means of special filters comparative measurements of the size of these supposed particles have been made, although it can hardly be accepted that the precautions adopted and the results attained are by any means beyond reproach. Further work along these lines will have, in my opinion, a very important bearing on the scientific problems of the cell. With the aid of the ultra-microscope and the assistance of bio-physics possibilities are offered, after establishing beyond doubt the existence of a particulate virus, for determining the relation of, say, protein molecule or molecular aggregate to micella and to the ultimate particle which patently carries all the attributes of living matter.

Less than a century ago the enunciation of the cell theory opened up a new line of attack on biological problems, and this idea began quickly to dominate biological thought. Thus it came about that the cell theory was accepted as fundamental to biology as the atomic theory to chemistry, and the present status of biological science rests on the advancements made by the adoption of this cell theory which offered to the world the idea of a unit or entity which marked the starting point of the animal or plant individual, and dominated the make-up of the fully grown animal. From a historical standpoint it is of interest to record the activities of a group of naturalists who, at the period referred to, were developing a knowledge of the facts demonstrating the idea of organic evolution. Their investigations proceeded along independent lines, taking no cognisance of the newly discovered basic unit. This was actually the position when the idea of organic evolution had taken concrete shape in the hands of Darwin. During the last quarter of the nineteenth century the clearer conception gained of the cell led to a great advance of our knowledge of this unit of the animal and plant bodies, and such studies began to link together the problems of structure, development, growth, heredity, and evolution. The beginning of the twentieth century initiated a series of illuminating advances which have served to encourage biological knowledge of a more exact and quantitative order, and are yearly bringing us to a more profound and fundamental outlook on the problems of living substance. By a strange coincidence the rediscovery of Mendel's Laws of Heredity was made in the year 1900 by three independent workers, and the theoretical interpretation of the phenomena dovetailed in a most complete and satisfying way into the development of knowledge on the cytological side. Since that year our knowledge of the cell has forged ahead, and all this has served to substantiate more and more strongly the aphorism *omnis cellula e. cellula.* The idea that the cell represents the ultimate unit of life or living material has thus become more and more the working idea of the biologist,—at least, in so far as the individual organism is concerned. The complexity of the cell with its organisation slightly more comprehensible to us to-day lends very little weight to any idea of the possibility of cells arising *de novo* or by any form of spontaneous generation. Our knowledge of bacteria has added weight to this attitude and helped very materially to effect a sort of stabilised position in so far as the cell theory is concerned. Even when danger threatens by the inability to determine under the microscope a specific organism, its ultra-microscopic nature and filterable size was accepted, and yet the cellular entity of the organism maintained.

For a very long time—in fact the old idea still persists in the minds of many—it was believed that protoplasm possessed a definite physical structure, and such structure was regarded as a necessary feature of protoplasm, enabling it to discharge its vital functions. The heterogeneity of the particles commonly found in the cytoplasm led to the elaboration of various theories of visible structure, such as the reticular, alveolar, granular, etc., theories. The position at the present day is that there is no acceptable theory of visible structure, and the appearances of oftclaimed structure are regarded either as temporary phases in the individual cell or as artifacts. The development of reticular and alveolar structure as the result of experiments in the coagulation of solutions of albumens, etc., has been demonstrated. The adoption of this idea is not tantamount to denying an organisation in protoplasm, but any fundamental structure is certainly of an ultra-microscopic order. Recent work along the line of micro-dissection of cells demonstrates very definitely the absence of any plan or organisation of a grosser or visible order. The activities of protoplasm are carried through in a visibly homogeneous mass that subscribes to the condition of a colloid, such a nature being demonstrated by its behaviour and not structure. When structures do appear at times within the protoplasm of the cell the decision as to whether they are to be regarded as living or non-living structures exercises no prejudical influence on the conception that protoplasm has an ultra-microscopic fundamental make-up.

While the idea of a grossly homogeneous protoplasm represents a modern point of view, the suggestion that it possesses an ultra-microscopic pattern is by no means new. Hosts of investigators have suggested such a metastructure, and have offered definite names and functions for the particles which were regarded as of the order of aggregates of molecule or micellæ, capable of growth and division. I need refer only to a few of these, such as the physiological units of Spenser ; Darwin's gemmules ; de Vries' pangens ; Nageli's micellæ ; Altmann's bio-plasts ; Weisman's bio-phors. Such ideas of ultra-microscopic units have met with much opposition from cytologists, who regarded cell structure as the last word in the structure of protoplasm. The modern view of geneticists that there exist in the nucleus particles of specific make-up responsible for definite characteristics of the individual organism must stand for the present, in view of the success in interpreting genetic problems that result from the adoption of the idea. What obtains in the nucleus might reasonably occur in the cytoplasm. If we are prepared to retire from a prejudiced position which would regard the cell as not merely a colloïdal system but as the ultimate entity in so far as life is concerned, and to examine the matter from the standpoint of evolution, the existence of virus particles possessing the power of growth and reproduction would appear to offer ground for adopting a broader and more constructive view of the cell.

If living substance was derived originally from non-living material, that is to say, there has been a transformation of inorganic to organic, then surely there must have been stages in that evolutionary scheme when something much more primitive and less highly organised than the cell represented the living material, and to that something we must give a particulate nature. While admittedly there are shown, among living cellular organisms, varied conditions of differentiation with respect to cytoplasm and nucleoplasm, yet even in the simplest of these there is a complexity of structure and organisation which defies us in any attempt to regard them as approaching in simplicity the earliest forms of life.

There are, within the cytoplasm and nucleoplasm of cells, bodies which maintain their identity and autonomy and possess the power of reproducing themselves. I refer to structures which are actually visible under the microscope, such as plastids ; but on top of this again, we impress the idea of certain hypothetical, ultra-microscopic particles which likewise possess the power of self-propagation and independence, such as the genes whose existence, based on the result of accurate genetic studies, can be assumed with as much assurance as that of atoms and molecules. The term " living " may have absolute or relative significance for different minds, but adopting the qualities by which we are accustomed to distinguish living from non-living material, we must bestow the term "living" on such visible masses as plastids ; and such hypothetical bodies of a smaller order as genes. We may readily attribute to such particles as genes, which, in the present state of our knowledge we regard as the agents responsible for the carrying of specific qualities to the individual, that is, to the cell, an individuality of an intrinsic order—something, may I be permitted to say, corresponding to what we have learned to speak of within recent years as the psychical element of psychism.

It is no doubt desirable in a scientific paper to restrict oneself to the detailing of facts, reasonings, and observations, and to refrain from any ultra-imaginative effort to construe the meaning of such except along such lines as might be regarded, from the scientist's standpoint, as fully justified by the facts. In a Presidential Address, however, one may, perhaps, claim a little license and depart so far from the purely scientific arena as to venture on to ground which is the prerogative of the metaphysicist. Chemistry and Physics have been fundamental to a comparative understanding of biological problems, but it may be said with as much truth that biology has much to offer those sciences for an understanding of Nature. The ultra-materialistic attitude which would, in uncontrolled language, express itself by alleging that the problem of life is interpretable in terms of the laws of chemistry and physics, fails to recognise that the dominion of physics, for example, has been so widened as to now vaguely include the very problems which lie intrinsically at the basis of life, and that a wider interpretation of biological science may render clearer to the physicist many of these fundamental problems. The developing knowledge of to-day suggests that biological science requires, for the elucidation of its problems, more than the application of known physical and chemical laws. The living cell is a psychic unit. Whether that psychism is restricted to the organic world we do not know—so far, needless to say, it has not called for specific consideration by the chemist or physicist. No doubt when we know more of the ether and of the fundamental relation of space, time, and thought, an appreciation of psychism will be dominant in the mind of the future bio-physicist and bio-chemist. Is the ether particulate ? Is there a unit of psychism ? What is the relation of such a psychon to the ether, etherion, electron, atom, molecule, gene ? Such are problems which are suggested in any attempt to interpret aright the make-up and genesis of the cell.

The development of the idea that the cell was a biological unit was accompanied by what is regarded as definite disbelief of the possibilities of spontaneous generation. The idea that an organised cell could arise in any way other than as a descendent of a pre-existing cell would to-day be regarded as preposterous, and rightly so, in view especially of what we know of the complexity of cell architecture. All this points in the direction of suggesting that the organised cell arose at some definite period in the history of the earth, and that the necessary conditions then existing no longer obtain. The exact nature of those conditions we do not know, although many theories are advanced. Foremost among such theories, and probably meriting major support, although relegated to the status of speculation, are such as attempt to associate the origin of living matter with the special phase of solar-irradiation; accompanied by special conditions obtaining on our planet at that time. Developments in physics during recent years would seem to lend some weight to this idea, as also do the results attained chemically by the utilisation of ultra-violet rays in certain otherwise impossible chemical syntheses. On the whole it would appear that the other sciences uphold the biological argument with respect to spontaneous generation in so far as the cell is concerned.

I do not feel it incumbent on me to meticulously follow through the stages in the evolution of the cell. Such would be an impossible task—a mere speculation without even any supporting gesture of fact.

The general theme which I have so far outlined to you suggests that the protoplasm of the cell is particulate, that these particles possess the attributes of life, and that such probably represented a stage of living matter antecedent to the organised cell. How and why that organisation was affected I would not attempt to postulate, nor would one care to pronounce definitely that the particles which are postulated as the component units of protoplasm cannot arise *de novo* at the present time, although the acceptance of such a possibility would be very difficult. I may, however, refer to the fact that in the investigation of virus diseases the possibility of a development of the disease *de novo* is rightly kept in view. So far there has been no record of any observations carrying the weight of evidence behind them in support of such an idea, which quite possibly might be used as an argument, but certainly not convincing, in favour of the particulate nature of the virus.

Such ultra-microscopic particles entering into the make-up of protoplasm might be regarded as endowed with specific qualities—possibly endowed with psychism—and the characteristic qualities of the cell would be determined by the inter-reaction of the various particles in much the same way as it is considered by geneticists that the genes in the chromatin of the nucleus exert their influence. What the nature of these bodies from a physical or chemical standpoint would be we do not know, but our ignorance in that respect could be attributed to the same cause as our ignorance of many things, physical and chemical, of a fundamental order.

The latter part of this address may appear to be far removed from the subject of virus diseases, but I have attempted to indicate that the study of virus diseases has a truly scientific interest far beyond that of a mere economic order. Some observations made by an American worker less than three years ago bring out the connection between the earlier and later parts of this address in a very suggestive way. This worker claimed to have produced a mosaic disease in tobacco by inoculation of the tobacco plant with extracts from what appeared to be normal and healthy potato plants. If such observations are proved to be correct, and if the particulate nature of the virus were substantiated, then it might be suggested with much reason that the origin of virus diseases might lie in the transportation of minute living particles from one species of a plant to another. In the experiment mentioned, the two species are comparatively closely allied, and, adopting the idea of genetic relationship, we might regard the particle from the potato substance as being sufficiently closely allied to the particles entering into the make-up of the cells of the tobacco plant as to ensure their fitting in with the scheme of organisations which constitute tobacco cell life, but at the same time sufficiently foreign or riotous as to engender a pathological condition. The experiments just outlined have not been substantiated, but at least they suggest a sane possibility for the origin of virus diseases, and furthermore, indicate that possibly insects which, as we have seen, play an important part in transmitting various virus diseases, may have been responsible for the origin of these diseases. We have a parallel in the case of many protozoan parasites where we find forms restricted to the alimentary canal of insects, and other closely allied forms which spend part of their time in the alimentary canal of insects, and other phases of their existence as parasites in the blood system of other animals, the insect serving as the vector. Aphides in particular play a very important part as vectors of virus diseases, and, it is noteworthy, the meristematic tissues at the growing point are particularly attractive to aphides. Further, aphides in general have a complicated life-history, and during that life-history they become variously adapted in many cases to different host plants. All this is very suggestive.

The field of virus disease is thus a very attractive one, and must ultimately enlist the interest of the future bio-chemist, and notably of the future bio-physicist. The study of these diseases combines in an excellent way attractions for the pure biologist and the economic biologist.

Investigation into Sewage Disposal in the Brisbane Estuary.

By J. V. DUHIG, M.B., Director, Brisbane and District Laboratory of Pathology.

(Three Text-figures.)

(*Read before the Royal Society of Queensland, 30th April, 1928.*)

At the request of the old Metropolitan Water Supply and Sewerage Board, I made an investigation into the Board's method of disposal of sewage into the estuary of the Brisbane River. It had been suggested that this method was or was likely to be a nuisance and/or a danger to the public health.

In this work I collaborated with Mr. Thom, Sewerage Engineer to the Board (who has supplied me with all the engineering data) and with Mr. Chamberlain, the Board's chemist, who not only assisted in the actual work in the field but also supplied check results of the chemical tests used in examining water samples taken.

The results given are those of bacteriological and chemical examinations of samples of water taken in conditions set out in the tables.

In an investigation of this kind, the only result possible is to show whether a sewage disposal system of a given kind is or is not suitable for a given place. The conditions in which this system functions are so numerous and vary so much individually from hour to hour that, in the present state of knowledge, I should hesitate to advise sewerage engineers to draw any but tentative conclusions from my findings. It is almost certain that in no other city in the world do conditions exist exactly analogous to those of the Brisbane system. All that it is desired to establish in this paper is:—

1. Whether the Brisbane method of sewage disposal is suitable for Brisbane in the sense that it can most economically dispose of sewage without subjecting the population to the risk of æsthetic annoyance and/or danger, and

2. That my methods are sound and universally applicable.

The conditions in which sewage disposal is conducted into the Brisbane estuary are as follow:—

1. Volume of sewage discharged.
2. Volume of diluent available.
3. Rate of flow of diluent.
4. State of the tide.
5. Direction of the wind.
6. Oxygen content of the diluent, depending on (*a*) salinity of the diluent, (*b*) temperature of the diluent, (*c*) barometric pressure, (*d*) depth of diluent.

The value of any method of sewage disposal depends on rapid oxidation of organic material and this in turn is a function of (*a*) the dilution available, (*b*) the oxygen content of the diluent.

All the above factors are taken into account in this investigation, although very early in its course it became evident that they could be disregarded as rigidly serious components of the problem under investigation. As will later be shown, for instance, wide variation in these factors would have had little influence on the safety of the particular system investigated.

I set out my findings under four heads:—

(A) Engineering data.

(B) Facts deduced from these data and from their operation.

(C) Facts obtained by experiment.

(D) Comparison with common standards.

(A) The main sewer from North Quay to Luggage Point is eleven miles long. The main sewer (diagram exhibited) varies in diameter from 2 ft. 6 in. at North Quay to 5 ft. at Luggage Point, and can carry 29,000,000 gallons of sewage per day. At Pinkenba the sewage is raised 50 ft., and at Luggage Point 30 ft., and at both these points is incidentally ærated. The volume of sewage discharged at Luggage Point outfall is now 4×10^6 gallons per day. This is equivalent to a depth of between 1 ft. and 1 ft. 6 in. in the 5-ft. sewer. The total volume of water passing Luggage Point in the Brisbane estuary is equal to about 200×10^6 gallons at any given moment at mean spring range.

The O_2 saturation of sea water containing 15×10^3 chlorides varies with the temperature as follows:—At 15° C. 8·63 parts per 10^6 to 7·15 parts per 10^6 at 25° C., sea water containing 20×10^3 parts chloride is saturated when it holds 8·14 parts of O_2 per 10^6 at 15° C. to 6·74 at 25° C. [1].

In my earlier tables I have shown the O_2 as parts per 10^6. In the later tables O_2 is shown only as percentage saturation, the amount per unit volume being easily available by calculation from the tables referred to in [1].

(B) From these data I have made the following general observations. The sewage from the city and suburbs of Brisbane is brought to Luggage Point through some miles of piping. On the way it is exposed in a relatively wide stream to the action of the atmosphere. It is pumped into sedimentation tanks provided with baffles to retain sludge. Here it remains many days.

Inspection of these tanks shows that only relatively less destructible matter, such as orange peel, insects, matches, fish-bones, &c., is not destroyed. The human waste is almost completely reduced to sludge by the time it leaves these tanks. From there it flows at a fast rate into the outfall sewer, and observation will show that in falling the 8 ft. or so against the sewer wall, efficient oxidation takes place so that by the time the sewage reaches the outfall the solid material is reduced to a sludge so finely divided that it takes some hours to settle even in so small a quantity as 1,000 c.c. of fluid. (*This fact was demonstrated before the Society.*) The risk of creating a nuisance is so small that it can be disregarded.

Colonel Longley raised certain objections to the Luggage Point site and works to deal with all the sewage on economic grounds alone. He advocated preliminary treatment of sewage in various suburban areas before final discharge at a point higher up the river than Luggage Point. The distance of travel must, however, be a matter of opinion. The establishment of subsidiary treatment works in settled areas would involve bitter opposition and very great expense as compared with Luggage Point which has, to my mind, certain outstanding advantages. (1) The relatively longer pipe line results, as I have shown, in oxidation which is so considerable as to be almost complete; (2) the Luggage Point area is not likely to be settled for a long time, if at all; (3) discharge into the estuary provides an ideal, because cheap and safe, method as against costly and possibly offensive suburban systems.

(C) I made seven examinations of Luggage Point effluent as it reached the estuary.

I. 16-11-27.

Wind N.E. moderate.

Tide—

Flood at beginning of experiment.

Slack at end of experiment.

Temperature of water 26° C.

Sewage flowing for three hours.

The effluent formed a sharply marked zone about 30 yds. wide immediately opposite the outfall. The sharpness of the line is indicated in the plate counts shown in Table I.

TABLE I.

Origin of Sample.	Plate Count per c.c.	O_2 in Solution. Parts per 10^6.	Chlorine content. Parts per 10^6.	O_2 Saturation %.
1. Centre of "zone"	Uncountable	3·3	15 x 10^3	50
2. Edge of zone	Uncountable	3·1	20 x 10^3	33
3. 100 yds. east	2	4·02	20 x 10^3	62
4. 50 yds. south	1,600	5·15	20 x 10^3	79
5. 100 yds. south	4,250	5·25	20 x 10^3	80
6. 200 yds. south	640	5·30	20 x 10^3	80
7. 400 yds. south	344	4·95	20 x 10^3	76
8. 500 yds. south	80	6·4	20 x 10^3	99
9. 10 yds. inside zone (north) ..	Uncountable	4·75	20 x 10^3	73
10. 30 yds. north of zone	45	..	20 x 10^3	..
11. 100 yds. north of zone	15	5·23	20 x 10^3	80

The area examined was shaped as shown in Map 2 (Text-figure 1).

Samples taken are shown thus in map:—·1, ·2, &c.

The plate count of Sample 3 shows the sudden drop in pollution just outside the "zone," and shows how restricted is the polluted area. As the effluent is dispersed by the tide the pollution is reduced to vanishing point.

O_2 Saturation (on which disinfection depends)—The high saturation in Sample I. is quite evidently due to the relatively low Cl content due to admixture with fresh water. The whole table shows how much more pollution the water would stand before oxygenation would cease.

II. 21-11-27.

Wind E., moderate.

Tide—Slack, at end of ebb.

Temperature of water, 27° C.

Sewage had been discharging many hours.

It was intended to investigate the northern end of the zone, but so many banks were uncovered that the launch could not cope with the projected investigation. However, the results obtained are as follows:—

TABLE II.

Origin of Sample.	Plate Count.	Cl Content. Parts per 10^6.	Cl Content. Parts per 10^6.	O_2 Saturation %.
1. Centre of zone	Uncountable	6·0	15 x 10^3	87
2. 50 yds. east	Very low	6·6	20 x 10^3	100
3. 100 yds. south	17,000	5·5	20 x 10^3	83
4. 200 yds. south	9,600	5·45	20 x 10^3	82
5. 400 yds. south	12,000	3·05	20 x 10^3	33
6. 600 yds. south	4,000	5·3	20 x 10^3	81
7. Lighthouse	1,720	6·0	20 x 10^3	92
8. Lytton	10	6·15	20 x 10^3	97
9. Pinkenba Wharf	300	..	..	..

See Map 3 (Text-figure 2).

All these samples were taken within 30 yds. of the shore of the sewage reserve, and still show rapidly diminishing pollution owing to dispersion and oxidation. It will be noted that the pollution at Pinkenba wharf is almost as bad as that 400 yds. south from the outfall after a two-hours' "run" on a flood tide. The oxygen content still remains high enough to deal effectively with the pollution.

III. 8-12-27.

Wind E., strong.

Tide—

Half hour before end of ebb at beginning of experiment.

Slack at end of ebb at end of experiment.

Temperature of water 26° C.

Sewage running two and a-half hours.

Table IIIA deals with samples taken within 20 yds. of the shore to the north of the outfall.

Table IIIB deals with samples taken just off the shore.

TABLE IIIA.

Origin of Sample.	Plate Count per 1 c.c.	O_2 Content. Parts per 10^6.	Cl Content. Parts per 10^6.	O_2 Saturation. %.
1. 50 yds. north of centre of zone	Uncountable	1·2	20×10^3	18
2. 100 yds. north of centre at edge	Uncountable	1·0	20×10^3	15
3. 100 yds. north of centre over edge	700	1·5	20×10^3	22
4. 200 yds. north	800	..	20×10^3	..
5. 300 yds. north	600	2·5	20×10^3	37
6. 400 yds. north	700	2·2	20×10^3	33
7. 450 yds. north	700	2·6	20×10^3	40
8. 500 yds. north	300	3·9	20×10^3	59
9. 550 yds. north	60	7·0	20×10^3	100
10. 600 yds. north	500	4·3	20×10^3	65

See Map 4, which shows area of investigation set out in Tables IIIA and IIIB (Text-figure 3).

TABLE IIIB.

Origin of Sample.	Plate Count per 1 c.c.	O_2 Content. Parts per 10^6.	Cl Content. Parts per 10^6.	O_2 Saturation %.
1. 100 yds. north	Uncountable	1·0	30×10^3	C 17
2. 200 yds. north	600	1·2	30×10^3	C 20
3. 250 yds. north	1,040	1·5	30×10^3	26
4. 300 yds. north	500	2·0	30×10^3	34
5. 350 yds. north	1,280	..	30×10^3	..
6. 400 yds. north	400	3·6	30×10^3	62
7. 450 yds. north	150	5·0	30×10^3	86
8. 500 yds. north	426	3·8	30×10^3	65

See Map 4 (Text-figure 3).

The samples dealt with in Tables IIIA and IIIB were taken simultaneously and independently. They show that, on the ebb tide and with a strong easterly breeze, pollution is pretty uniform for a considerable distance northwards along the estuary, though the zone is extraordinarily narrow—not more than 25 yds.

The low oxygen saturation is striking and must evidently be a function of the shallowness of the water on the end of the ebb tide, probably due to evaporation and redissolution of inorganic salt from the silt, resulting in a greatly increased Cl content.

IV. 20-3-28.

Tide—Ebbing.

Work commenced about 2.15 p.m.

Work finished at 2.45 p.m.
Low water at 2.57 p.m.
Sewer discharging six hours.
Wind S.E. by E. fresh.
Temperature of water, 26° C.

TABLE IV.

	Origin of Sample.	Plate Count per 1 c.c.	O_2 Saturation %.
1.	Southern end of " Zone" *i.e.*, 40 yds. south of outfall	2,280	60
2.	Just at edge of zone, *i.e.*, 40 yds. south of outfall ..	1,224	86
3.	20 yds. off shore opposite outfall	1,480	77
4.	Inside edge of zone (20 yds. off shore), 100 yds. north of outfall	784	81
5.	200 yds. north of outfall	1,040	92
6.	300 yds. north of outfall	896	88
7.	400 yds. north of outfall	1,000	90
8.	500 yds. north of outfall	1,520	87
9.	600 yds. north of outfall	760	88
10.	700 yds. north of outfall	964	Not taken
11.	800 yds. north of outfall	1,040	Not taken
12.	900 yds. north of outfall	1,280	86

It will thus be seen that—

1. On the ebb tide no sewage can travel any but a very short distance upstream. In this case the zone to the south of the outfall was very sharply defined and extended up stream only about 40 yds.

2. Under the influence of the wind and tide-stream the zone of pollution is very narrow, estimated at 25 yds. at its maximum.

3. Owing to eddies the pollution is neither uniform nor uniformly graduated downstream. It is almost as heavy 900 yds. north of the outfall as at the outfall, showing how thorough mixing must be under the influence of wind and tide.

4. The pollution is obviously very slight, only one plate showing a count of over 2,000 organisms per 1 c.c.

5. The pollution is indeed so slight that the oxygen saturation (which is an index of the sterilising power of the water) was reduced at its lowest, by only one-third. In all cases it still remained very high indeed. So that even in the polluted area the water still retained a very high proportion of its sterilising power.

V. 14-4-28.
Wind S.W., light.
Tide—
Ebbing.
Low water, 11.5 a.m.

Work started at 10.45 a.m.
Work stopped at 11.8 a.m.
Sewage discharging 16 hours up to 10 a.m.

TABLE V.

Origin of Sample.	Plate Count per 1 c.c. Parts per 10^6.	Chloride Content. Parts per 10^6.	O_2 Saturation %.
1. Beacon A*	2,080	15 x 10^3	88
2. 50 yds. north of beacon A	2,800	15 x 10^3	81
3. 100 yds. north of beacon A	3,080	15 x 10^3	85
4. 150 yds. north of beacon A	2,320	15 x 10^3	88
5. 200 yds. north of beacon A	3,520	15 x 10^3	88
6. 250 yds. north of beacon A	2,360	15 x 10^3	80
7. 300 yds. north of beacon A	1,440	15 x 10^3	88
8. 350 yds. north of beacon A	1,160	15 x 10^3	82
9. 400 yds north of beacon A	1,200	15 x 10^3	74
10. 450 yds. north of beacon A	1,320	15 x 10^3	86

Just before this investigation, sewage had been running into the estuary from within 2 hours 20 mins. of low tide on the night of 13-4-28, continuously through the flood tide from 9.24 p.m. that evening until the "turn" at 4.1 a.m. on 14-4-28, and continued on the ebb until stopped at 10 a.m., 14-4-28, about an hour before low water.

VI. Table VI. shows plate counts of samples of water taken within 25 yds. of the shore with the wind slightly onshore. The average depth of the water was about 3 ft. 6 in. The plate counts are all very low and the O_2 saturation always remains high.

14-4-28.
Wind S.E., fresh— i.e., blowing onshore.
Tide—Flood (2 hours 10 min. after turn).
Work started at 1.15 p.m.
Work finished at 1.50 p.m.
Sewage stopped discharging after 16 hours run up to 10 a.m. 14-4-28 (See Table V.).

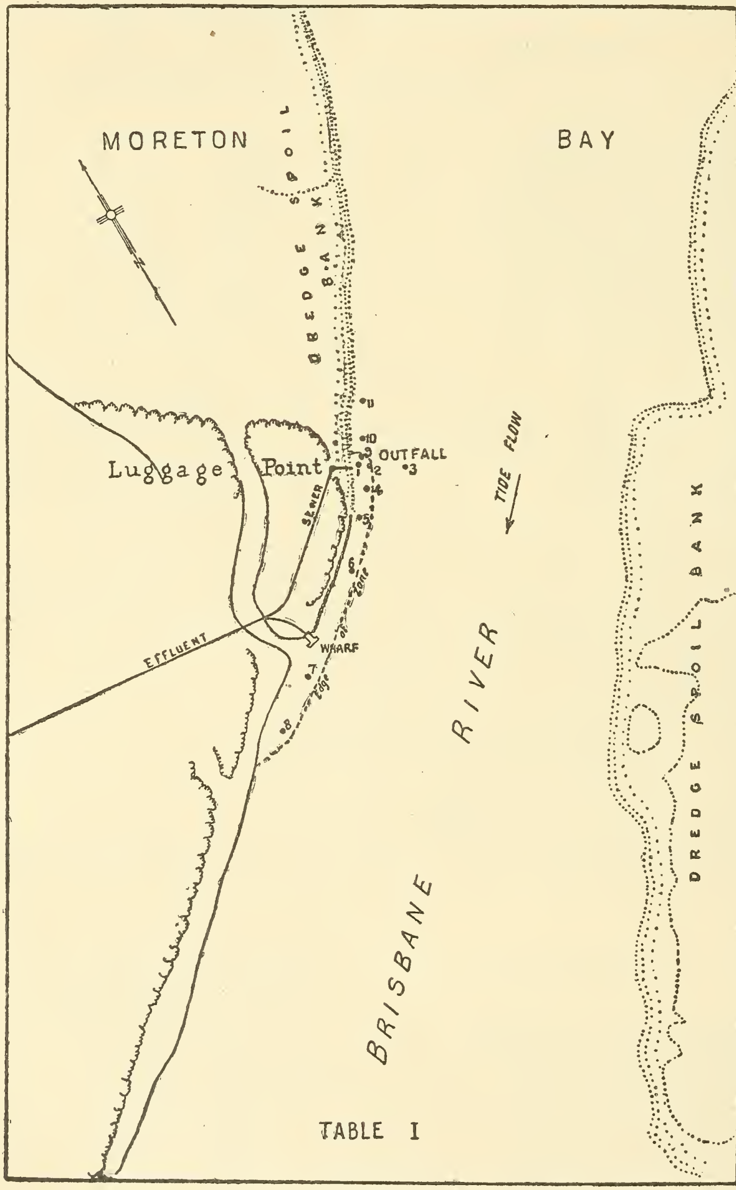
TABLE VI.

Origin of Sample.	Plate Count per 1 c.c.	Chloride Content. Parts per 10^6.	O_2 Saturation %.
1. 200 yds. south of beacon A*	1,000	20 x 10^3	84
2. 500 yds. north of outfall	*See* † note.	20 x 10^3	81
3. 400 yds. north of outfall	210	20 x 10^3	89
4. 300 yds. north of outfall	990	20 x 10^3	85
5. Outfall	10,080	20 x 10^3	85
6. 100 yds. south of outfall	640	20 x 10^3	84
7. 200 yds. south of outfall	1,120	20 x 10^3	86
8. 300 yds. south of outfall	960	20 x 10^3	90
9. 400 yds. south of outfall	840	20 x 10^3	89
10. 500 yds. south of outfall	760	20 x 10^3	85

* Beacon A is about 900 yards N. of the outfall.

† Sample II. was contaminated by tap water during manipulation, and colonies of *B. subtilis* vitiated the accuracy of the plate count.

From this table it seems reasonable to assume that considerable sterilisation has taken place downstream, but that also some portion of the sewage remains as a residue in the zone at the outfall and is washed upstream on the flood tide.



Text-figure 1.

Subcultures were made of colonies selected at random from plates inoculated from water which is treated in Tables V. and VI. Two plates yielded lactose-fermenting organisms, but their distribution was so capricious I think it quite possible that similar organisms could be found in other situations. It must, however, be stated that the organisms which predominated most definitely in plates made from water at a distance from the outfall were fluorescent bacilli which did not ferment lactose but invariably fermented dextrose, and capable apparently of longer survival than those organisms usually regarded as significant of fæcal contamination.

VII. 17-4-28.

Wind S.E., fresh.
Tide—Ebbing.
Low water 1.39 p.m.
Work started at 12.15 p.m.
Work finished at 12.45 p.m.
Sewage discharging up to 11.30 a.m.
Temperature of water 18° C.

TABLE VII.

	Origin of Sample.	Plant Count per 1 c.c. Parts per 10^6	Chloride Content. Parts per 10^6	O_2 Saturation %.
		Parts	per 10^6.	
1.	30 yds. south of outfall	900	15 x 10^3	Not < 90
2.	Outfall	500	15 x 10^3	Not < 90
3.	20 yds. east of outfall	300	15 x 10^3	Not < 90
4.	50 yds. north of outfall	600	15 x 10^3	Not < 90
5.	100 yds. north of outfall	700	15 x 10^3	Not < 90
6.	200 yds. north of outfall	450	15 x 10^3	Not < 90
7.	300 yds. north of outfall	800	15 x 10^3	Not < 90
8.	400 yds. north of outfall	1,300	15 x 10^3	Not < 90
9.	500 yds. north of outfall	880	15 x 10^3	Not < 90
10.	600 yds. north of outfall	570	15 x 10^3	Not < 90
11.	700 yds. north of outfall	320	15 x 10^3	92
12.	800 yds. north of outfall	400	15 x 10^3	Not < 90

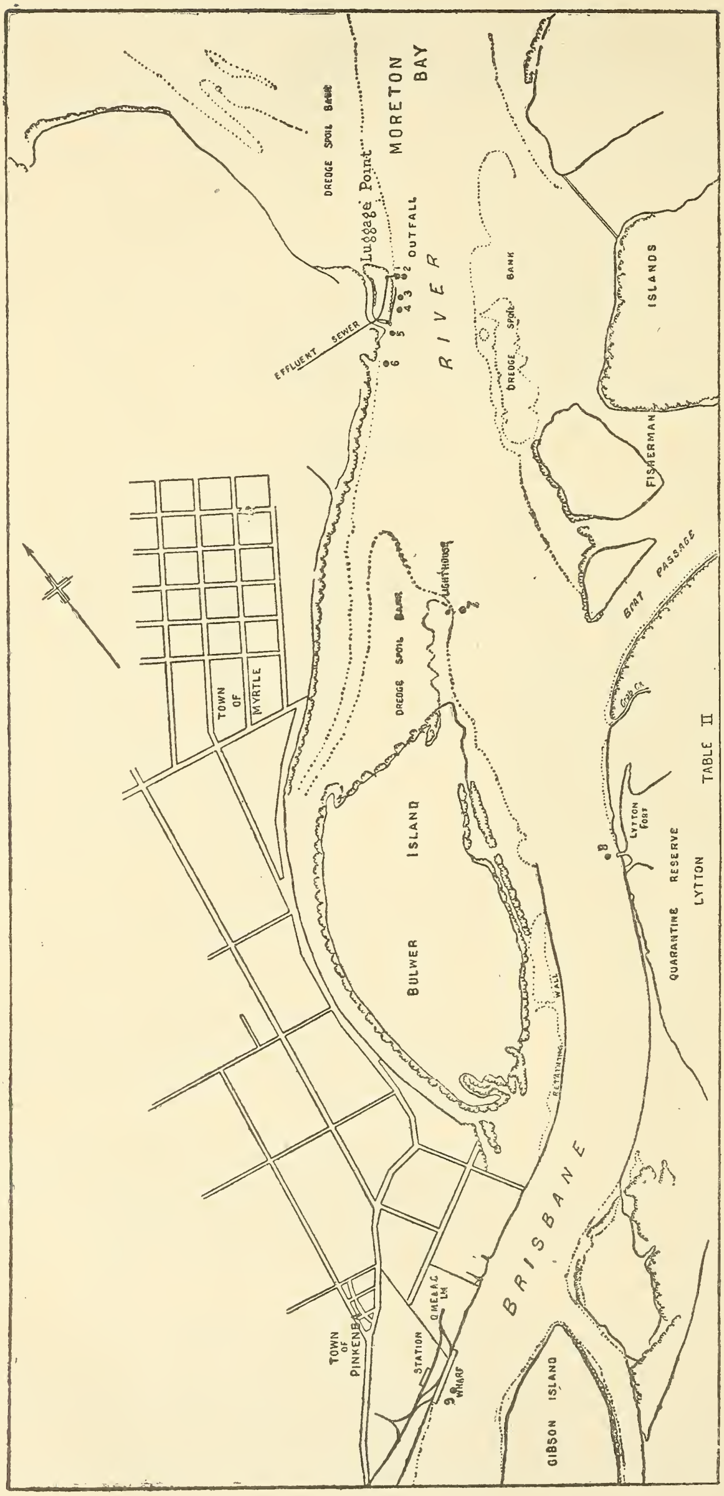
All of these samples were taken close inshore (average distance from sandspit 25 yds.).

Random samples were taken of suspicious colonies for the presence of lactose fermenters, and these appeared in one sample in four on an average. One sample incidentally yielded a streptococcus which is receiving special bacteriological attention.

(D) Standards to regulate sewage disposal are surprisingly few, probably for the season that the relevant factors vary within such wide limits. As I noted in the beginning, it would seem that so far each system must be designed largely in accordance with favourable conditions.

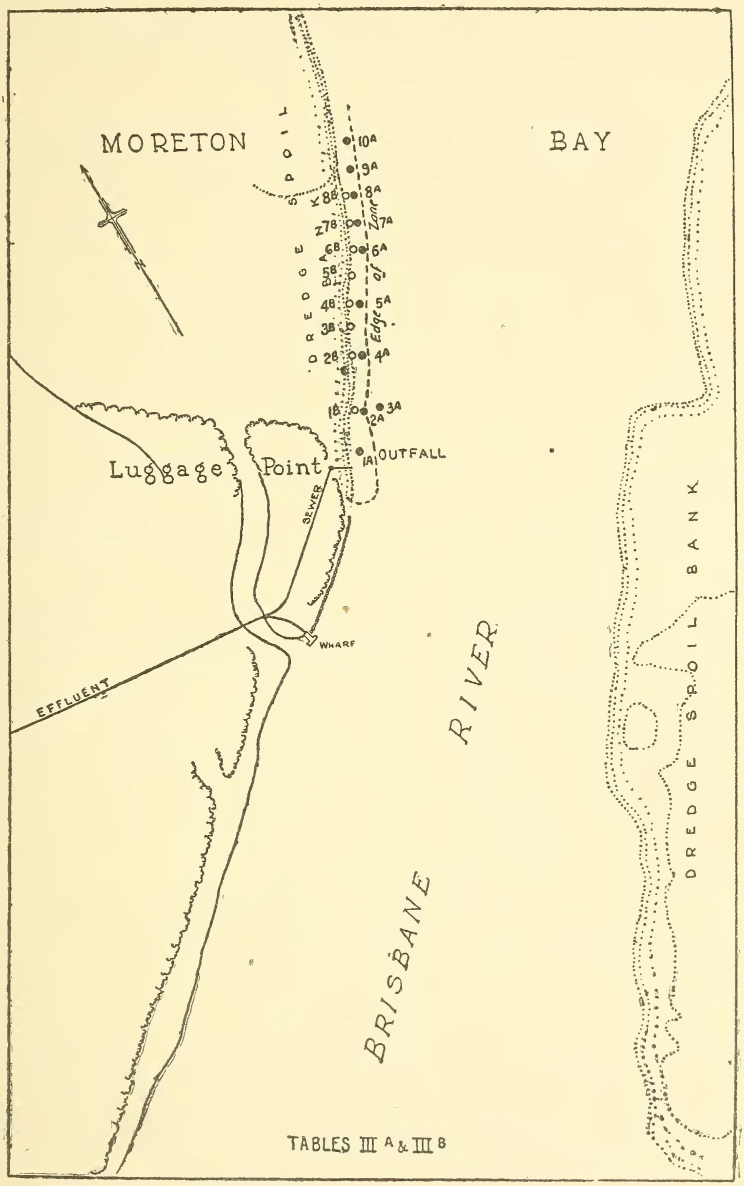
All the literature I have access to seems to show that—

1. "If 50 per cent. of the O_2 which a water can hold in solution is removed, it will not be offensive, but it can probably be distinguished from a well aerated water by those familiar with such conditions. . . . It is desirable to maintain an oxygen content in streams and natural waters somewhat higher than 50 per cent.



Text-figure 2.

". . . 70 per cent. saturation of O_2 would be a satisfactory limit to set as a criterion to determine the limit of pollution permissible in a stream." [2].



Text-figure 3.

2. The report of the "International Joint Commission on the Pollution of Boundary Waters" (1914) [3] seems to be concerned almost solely with inland streams and with the possible contamination of drinking water supplies, so that Clause 5 of their findings must apply more cogently still to estuaries. With respect to inland waters this Commission finds that, "In waterways where some pollution is inevitable and where the ratio of the volume of water to the volume

of sewage is so large that no local nuisance can result, it is our judgment that the method of sewage disposal by dilution represents a natural resource and that the utilisation of the resource is justifiable for economic reasons, provided that an unreasonable burden or responsibility is not placed upon any water purification plant and that no menace to the public health is occasioned thereby.''

The International Commission therefore believes that in certain conditions a simple dilution system of sewage disposal is adequate even when the diluting water may be required for human consumption.

3. The Eighth Report of the Royal Commission on Sewage Disposal (1912) [4] was apparently also addressed to pollution of inland streams and the only relevant portion of its findings is that ''with a dilution of over 500 volumes all tests may be dispensed with and crude sewage discharged, subject to such conditions as to the provision of screens or detritus tanks as might appear necessary to the central authority.''

4. Metcalf and Eddy [3] quote Dr. Dunbar, ''Principles of Sewage Treatment.'' He says, ''The question of sewage disposal is intimately bound up with that of spreading epidemics by means of polluted rivers,'' (i.e., by drinking, bathing, infection of sea food), ''and measures to be adopted can only be decided upon after due consideration of all local conditions.''

5. Colonel Longley's standards (2) do not seem universally acceptable. The Metropolitan Sewerage Commission of New York advised a minimum of 4·3 parts O_2 per million in New York Harbour equal to 58 per cent. saturation. Mr. Fuller reported to his Board on this finding that he considered this standard needlessly high. He considered roughly 2·1 parts O_2 per million a safe lower limit under proper conditions, these being that sewage sludge shall not be allowed to accumulate to such an extent as to become a serious factor in absorbing O_2 from the water.

6. Many other authorities agree that no uniform standard can at present be laid down. O_2 is a rough guide, but local conditions should be taken into account.

Discussion.

There is no reason for believing that Luggage Point sewage outfall and treatment station are now or can be a nuisance. The determination of a nuisance is a function of the normal sense of smell. I and my assistants in this investigation did not detect any offensive smell at any point of the sewage line, excepting perhaps a more than fairly perceptible one just above the incoming sewage flow at the Luggage Point pumping station.

This finding could have been forecasted from a consideration of the system. I should expect to find a more intense odour higher up the system than at Luggage Point, since by the time sewage reaches the treatment works oxidation and mechanical division of sewage has taken place.

After discharge into the estuary the sewage still has a high bacterial content. From a review of the tables it seems evident that dilution dispersion and destruction of fæcal organisms are very rapid. The tables show that pollution of a very narrow strip of the estuary is small, no greater indeed than that of most inland streams or than that of large watercourses flowing through cities.

In the Brisbane estuary the polluted strip of water is relatively narrow, of the order of about one-thirtieth of the width of the total available diluent.

I found that shortly before and at low water, i.e., soon after the period most suitable for discharge, the depth of the polluted zone varied within very narrow limits—from zero to a maximum of 4 ft. 6 in.

The reason for this is almost solely because the winds prevailing in the estuary for periods other than those of the short infrequent westerly winds come from the easterly side of the compass and tend to drive the sewage onshore.

This fact raises an interesting question. Since the public are terribly frightened of germs, it seems that our duty is to destroy them, at least those that come down in sewage. This is a great pity, because sewage is incomparably the best fertiliser we have, and Chinese society has a distinct advantage because it uses sewage to enrich its agricultural yield. Since, however, we have decided to destroy as well as we can our nitrifying bacteria by heavy dilution and consequent dispersion and oxidation, we should make a thorough job of it.

In the case we are investigating we see that quite a considerable amount of the bacterial content of the sewage is blown onshore. It is evident that on a receding tide quite a considerable number of organisms must be deposited in the silt. Here they die when exposed to the sun or are washed off again and destroyed by the incoming tide. If this silt is not to be used as manure, as it could be, and if these really beneficent germs frighten good citizens, the complete job of their destruction would best be accomplished by using the deep water more than 30 yds. offshore for their final discharge. At present it is very evident from the maps and tables that the work of bacterial destruction could better be accomplished by continuing the outfall sewer into much deeper water than that into which it now discharges.

Even now it is evident that sewage pollution of the estuary is very low. It can be dangerous only if the salt water about half-a-mile above and below the outfall is used as drinking water or if sea food taken within that range is consumed. Even in the present state of the law which permits the sale of oysters and fish taken on foreshores immediately adjacent to the outfall, infection of the population in this way is a matter of pure chance, as my discussion of the tables shows. Our samples show that in a very high percentage of cases in which sewage discharge is regulated to produce the best hygienic results no fæcal contamination can be detected.

Conclusions.

1. The present method of disposal of sewage into the Brisbane estuary is not a nuisance.

2. The sewage as discharged into the estuary contains solid matter only in a very finely divided state.

3. The bacterial content of the sewage is reduced with very great rapidity.

4. The total power of the water of the Brisbane estuary to render sewage innocuous is many multiples of that required at present.

5. The volume of water in the Brisbane estuary can effectually sterilise at a minimum twenty four hours' effluent within a time estimated at four hours from cessation of discharge at the outfall even at a maximum depth of 4 ft. of water.

6. Shallow water is not as good a diluent for sewage as deep water.

7. Onshore winds blowing on shallow water hinder dispersion and dilution.

8. Sewage disposal into the Brisbane estuary would be greatly improved by continuation of the outfall into deeper water. The optimal length of this continuation would be a function of the grade of the channel, and could only be determined by sounding experiments. From my investigations I conclude it should be not less than 50 yds.

9. At present the method of disposal is economically sound and perfectly safe provided that no shell fish is taken for human consumption from the shore 800 yds. above and below the outfall sewer, at a distance of 50 yds from high-water mark.

10. The most perfect hygienic result can be obtained by sewage discharge lasting from the end of flood tide until within an hour of the end of the ebb tide.

11. All these conclusions may be altered by large increases in volume of discharge.

I must here record my thanks to Mr. Manchester (Chief Engineer, Water Supply and Sewerage Department, Brisbane City Council) for permission to publish these findings; to Mr. Thom (Sewerage Engineer) for advice; to Mr. Chamberlain for his assistance in chemical and field work and for arranging my itineraries; to the draughtsmen of the Sewerage Engineer's Department for so carefully preparing maps and diagrams; and to the staff of my laboratory for technical assistance.

REFERENCES.

1. Whipple, G. C., and Whipple, M. C. (1911)—Solubility of Oxygen in Sea Water. Jl. Am. Chem. Socy., 33, 362–365.

2. Longley, F. F. (1922)—Report to Federal Quarantine Department on Sewage Pollution of Streams.

3. Metcalf and Eddy—American Sewerage Practice, Vol. III.—"Disposal of Sewage"—pp. 32–36 (quoted by Longley).

4. Royal Commission on Sewage Disposal, 8th Report (1912).

Cinnamomum Laubatii—the Chemical Characters of the Essential Oils of Leaves and Bark.

By T. G. H. JONES, D.Sc., A.A.C.I.; and F. B. SMITH, B.Sc., F.I.C.

(*Read before the Royal Society of Queensland, 30th April, 1928.*)

Cinnamomum Laubatii (N.O. Lauraceæ) is described as a medium to large timbered tree, with leaves dark green above, inclined to whitish beneath, three to six inches long and one to two inches wide, with a prominent midrib, and two lateral veins arising from the base more or less parallel to the midrib and ascending to one-third of the apex. The flowers are borne in auxiliary panicles and the fruit is a berry seated in a somewhat enlarged perianth tube.

The Cinnamomums of Australia have been described by R. T. Baker [1], who establishes the specific rank of four Australian varieties, namely, *C. Oliveri, C. Laubatii, C. virens, C. propinquum,* distinguishing particularly *Cinnamomum Laubatii* from the Indian *Cinnamomum Tamala,* with which it had been previously considered identical [2, 3, 4].

Baker's determinations rest primarily on comparison of botanical features of authenticated specimens, but he further attempts to contrast chemical characters of essential oils and to correlate these with leaf venation and anatomy of the bark.

In his prosecution of this intention in relation to the Australian Cinnamomums, certain of Baker's assumptions on the chemical side appear unfounded.

The essential oils of penniveined *C. Oliveri* it is true are camphoraceous [5, 6], but as the present authors show, and contrary to Baker's assumption, those of penniveined *C. Laubatii* are not. Again, there appears no warrant for regarding *C. virens* as non-camphoraceous, and that the oils of the uninvestigated *C. propinquum* will be camphor-free is admittedly assumed on the ground of the trinervate character of the leaf.

Co-relation of the chemical characters of the essential oils of the Australian Cinnamomums with anatomical habit appears therefore to be unreliable. Nevertheless the specific independence of *C. Laubatii* and *C. Tamala* is fully borne out by the distinct characters of their essential oils. The leaf oil of *C. Tamala* consists largely of eugenol [7].

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1. Aust. Assoc. Adv. Sc., vol. xiii., 1912.
2. Bentham, Flora Australiensis, vol. v., p. 303.
3. Ewart, Proc. Roy. Soc. Vic., vol. xix.
4. Bailey, Queensland Flora, 1901, part iv., p. 1308.
5. H. G. Smith, Proc. Linn. Soc. N.S.W. 1897, p. 277.
6. Hargreaves, J. C. S., 1916, 109, 751.
7. Schimmel and Co. Report, April 1910.

The essential oils of *C. Laubatii* are shown by the present examination to be mainly sesquiterpene and sesquiterpene alcohol associated in the bark oil with safrol and in the leaf with terpenes and a small amount of cineol. No trace either of camphor or eugenol could be detected in the oils, which must therefore be regarded as non-camphoraceous and of little commercial value.

Experimental.

The material, verified as authentic, was supplied by the Provisional Forestry Board, Brisbane, from the Atherton Forest Station.

On distillation in steam—

60 lb. of crushed bark yielded 40 grammes oil (·15 per cent.).
120 lb. of crushed leaves yielded 70 grammes oil (·13 per cent.).

The small yields of oil (contrasting sharply with those from *C. Oliveri*) prevented complete and detailed examination of minor constituents, but the amounts available sufficed to demonstrate their main features. Both oils possessed agreeable odours, that of the bark suggesting safrol.

The following constants were determined (those of *C. Tamala* being included for comparison) :—

	C. Laubatii.		*C. Tamala.*
	Bark oil.	Leaf oil.	Leaf oil.
$d^{15.5}$	·9470	·9625	1·0257
$[a]_D$	+ 13	+ 8·5	+ 16·37
n_D^{20}	1·485	1·4848	1·5259
Ester value	10	18	Not available.
Acetyl value	39	63	Not available.

Agitation with appropriate reagents served to show in each oil absence of any but traces of phenols or extractable aldehydes or ketones.

Examination of the Bark Oil.

Thirty cubic centimeters of oil were fractionally distilled at 28 mms. pressure; only a few drops of oil distilled below 140 deg. C. The following fractions were collected :—

(*a*)	0° – 140° C	1 cc.			
(*b*)	140° – 150° C	5½ ccs.	$[a]_D$ + 11·5	$d^{15.5}$ ·9600, n_D^{20}	1·5005
(*c*)	150° – 160° C	12 ccs.	$[a]_D$ + 17·5	$d^{15.5}$ ·9312, n_D^{20}	1·5005
(*d*)	above 160° C	4 ccs.	$[a]_D$ + 20	$d^{15.5}$ ·9408, n_D	1·5005

leaving a small darkened residue in the flask.

Fraction (*a*) was too small for examination, but apparently consisted of a small amount of terpene.

Fraction (*b*) smelt strongly of safrol, the presence of which was determined by the formation of safrol nitrosite (M.P. 129 deg. C.). The density of the fraction indicated a safrol content of not more than 50 per cent., the remainder being sesquiterpene.

Fraction (*c*).—This fraction constituted the greater part of the oil, and as preliminary analysis indicated the presence of a sesquiterpene it was repeatedly distilled over metallic sodium, being finally obtained as a pale-yellow liquid with the following constants—

B.P. 150–155° C. (26 mms.)

$d^{15\cdot5}$ ·9242, $[a]_D + 16$ n_D^{20} 1·5005

[Found C = 88% H = 11·6 $C_{15}H_{24}$ requires C = 88·2 H = 11·8.]

Fraction (*d*) was essentially sesquiterpene together with a small amount of sesquiterpene alcohol.

The bark oil therefore contained safrol and a sesquiterpene, together with smaller amounts of ordinary terpene and sesquiterpene alcohol.

Examination of the Leaf Oil.

Fifty cubic centimeters of oil were fractionally distilled at 28 mms. pressure, and the following fractions collected:—

(*a*)	0 – 110° C	5 ccs.	$d^{15\cdot5}$	·8792	$[a]_D + 2\cdot5$
(*b*)	110 – 150° C	6 ccs.	$d^{15\cdot5}$	·9340	$[a]_D + 4\cdot5$
(*c*)	150 – 160° C	18 ccs.	$d^{15\cdot5}$	·9386	$[a]_D + 14$
(*d*)	above 160° C	6 ccs.	—		—

leaving an appreciable residue (15 ccs.) resinified in the distilling flask.

Fraction (*a*) was extracted with 50 per cent. resorcin solution and an absorption of 1 cc. (20 per cent.) occurred. The resorcin solution, on being examined in the usual way, gave a small quantity of cineol identified by formation of its iodol compound. The unabsorbed oil 4 ccs. evidently consisted of a mixture of terpenes. Negative tests were recorded for pinene, limonene, and phellandrene. The small amount available prevented further examination.

Fraction (*b*) consisted mainly of a mixture of (*a*) and (*c*).

Fraction (*c*) consisted of almost pure sesquiterpene, repeated distillation over sodium causing little diminution in volume. The purified substance possessed the following constants:—

B.P. 152–155° C. 26 mms.

$d^{15.5}$ ·9302 $[a]_D + 16$ n_D^{20} 1·5015

[Found C 88·1 H 11·5 $C_{15}H_{24}$ requires C 88·2 H 11·8.]

Fraction (*d*) was mainly sesquiterpene with some sesquiterpene alcohol.

The leaf oil therefore consisted of lower terpenes, some of cineol and a considerable proportion of sesquiterpene and accompanying sesquiterpene alcohol.

The similarity of physical constants suggests that the sesquiterpenes present in both oils are identical.

Both gave usual colour reactions with bromine vapour and with concentrated sulphuric acid characteristic of many sesquiterpenes of the Australian flora.

A Revision of Four Genera of Australian Scelionidae.

By Alan P. Dodd.

(*Read before the Royal Society of Queensland, 28th May, 1928.*)

This paper revises the Australian species of the genera *Hoploteleia* Ashmead, *Anteromorpha* Dodd, *Styloteleia* Kieffer, and *Phœnoteleia* Kieffer of the family *Scelionidæ* (Hymenoptera Proctotrypoidea); three species of *Hoploteleia* and one species of *Phœnoteleia* are described as new.

The genus *Hoploteleia* occurs throughout the world; *Styloteleia* and *Phœnoteleia* were not formerly recognised outside the Philippine Islands; *Anteromorpha* is common to Australia and the Hawaiian Islands.

Except in the case of the species of *Hoploteleia*, which are parasitic in the eggs of long-horned grasshoppers (*Tettigoniidæ*), the host relations of these insects are unknown.

STYLOTELEIA Kieffer.

Broteria, vol. 14, p. 184 (1916).

Female; Male.—Head, from dorsal aspect, transverse, about twice as wide as long, descending sharply to the occipital margin which is almost straight; from frontal aspect circular; lower frons faintly depressed and with a median carina; cheeks broad; mandibles tridentate; maxillary palpi 4-jointed; eyes large, bare; lateral ocelli against the eye margins. Antennæ 12-jointed; in the female with a stout 5-jointed club; in the male the flagellum filiform, the joints moderately long. Thorax, from lateral aspect, plainly longer than high, almost flat dorsally; pronotum hardly visible from above; scutum large, the anterior margin rather broadly rounded, the median lobe anteriorly with a small area separated posteriorly by a delicate transverse carina; parapsidal furrows complete and distinct; scutellum twice as wide as long, its posterior margin truncate or somewhat concave; metanotum in the male very transverse, not armed or prominent, its posterior margin straight; propodeum in the male moderately short, its posterior margin gently concave, without median or lateral carinæ, armed medially with a pair of well-separated stout teeth, the posterior angles faintly acute; metanotum and propodeum in the female broadly flattened or depressed, and hidden by the abdominal prominence, the propodeum on either side and wide apart with a delicate carina which may be raised at base in the form of a short tooth. Forewings long and broad, reaching the apex of the abdomen in the male, or failing by a little in the female; submarginal vein with a downward curve before joining the costa; marginal vein one-half to two-thirds as long as the stigmal, which is long and very oblique; postmarginal vein one-half longer or twice as long as the stigmal; basal and median veins indicated by brown lines. Legs slender; posterior tarsi no longer than their tibiæ, their basal joint longer than 2-5 combined. Abdomen slender, somewhat narrowed at base; in the female one and two-thirds to twice as long as the head and thorax united, elongate, fusiform, narrowly acuminate at apex; segment 1 not petiolate or subpetiolate, armed with a large stout horn that projects over the propodeum and metanotum or even over the posterior portion of the scutellum; 2 and 3 a little longer than 1 or 4; 6 as long as or longer than 4 and 5 united, transversely impressed or subdivided toward the middle and having the appearance of two segments, so that the abdomen appears to contain seven segments; in the male the abdomen is one-half to two-thirds longer than the head and thorax united, consisting of eight segments, 6 somewhat shorter than 5, the apical two segments very short and transverse.

Type.—*S. rufescens* Kieffer, Broteria, vol. 14, p. 185 (1916).

This genus was erected for the above species from the Philippine Islands. Through the courtesy of the late C. F. Baker, of Los Banos, Philippine Islands, I have had the opportunity of examining a paratype of *rufescens,* and am thus able to include three Australian species in the genus.

Styloteleia contains long slender insects with the general appearance of species of *Macroteleia* Westwood and elongate forms of *Baryconus* Foerster, from both of which genera it may be distinguished by the downward curve of the submarginal vein, and in the female by the apparent division of the apical abdominal segment. The abdomen is less narrowed at base than in *Baryconus,* and is not subpetiolate. The strong teeth on the propodeum are much larger than in certain species of *Baryconus,* where they are merely basal elevations of the median carinæ. The three Australian species are very similar.

STYLOTELEIA ACUTIVENTRIS Dodd.

Trichoteleia acutiventris Dodd, Royal Soc. of Qld., vol. 26, p. 98 (1914).
Trichoteleia novæ-hollandiæ Dodd, Archiv fur Naturgeschichte, Berlin, vol. 80 (1915).

Female.—Length, 3·20 mm.

Head black; thorax rich orange red, darker on the sides, the median lobe of the scutum mostly black; abdomen deep red, the apical segment blackish, the basal horn bright orange; legs bright golden yellow, the coxæ dusky; antennal scape and pedicel golden yellow, the funicle joints brownish yellow, the club black.

Vertex and upper frons with a few scattered fine punctures bearing fine hairs; a line of similar punctures on either side of frons against the eyes; cheeks with strong striæ converging towards mouth, smooth above except for a few punctures; vertex between the eyes rather wide, the lateral ocelli plainly farther from each other than from the median ocellus. Antennal scape moderately long; pedicel twice as long as its greatest width; funicle joints as wide as the pedicel; 1 slightly longer than the pedicel, 2 distinctly shorter than 1, 3-5 gradually shortening, 5 as wide as long; club 5-jointed, 1-4 each twice as wide as long, 3 slightly the widest. Thorax from dorsal aspect one-third longer than its greatest width; scutum stout, smooth, with a few rather small scattered punctures bearing fine hairs; parapsidal furrows coriaceous, wide apart, separated posteriorly by about two-thirds their length; scutellum with fine pubescence and a few punctures, its posterior margin gently concave; propodeum at base on either side of the abdominal horn with a stout upright tooth. Forewings failing by a little to reach apex of abdomen; somewhat brownish, the infuscation tending to form a longitudinal stripe; marginal vein two-thirds as long as the long oblique stigmal vein, the postmarginal twice as long as the stigmal; basal and median veins represented by thick brown lines. Abdomen twice as long as the head and thorax united, four times as long as its greatest width; segment 1 somewhat narrowed at base, almost as long as its posterior width, with a large stout horn projecting over the propodeum; 2 one-fourth longer than 1; 3 as long as 2, no longer than wide; 4 two-thirds as long as 3; 5 two-thirds as long as 4; 6 somewhat longer than 4 and 5 combined, the basal portion one-half as long as the narrow apical portion; 1 strongly striate, its horn smooth; 2 strongly striate, the striæ irregular except laterally, the surface between densely rugulose; 3 densely reticulate-rugulose, with several striæ laterally; 4 with similar sculpture but rather broadly smooth on posterior half medially; 5 and basal portion of 6 with a smooth median path, on either side with numerous pubescent punctures and fine surface sculpture; apical portion of 6 with fine striæ and pubescence; lateral margins of segments with fine pale hairs.

Male.—Length, 2.70 mm.

Scutum anteriorly with a few more punctures than in the female; posterior margin of scutellum straight; teeth of propodeum triangular, their inner margins oblique and almost meeting at base, their outer margins straight, their surface with two strong striæ. Abdomen two-thirds longer than the head and thorax united; sculpture failing medially on segments 4 and 5 and posterior half of 3; 6 with similar sculpture to 5; 7 and 8 very short. Antennal scape yellow, the pedicel dusky, the flagellum black; pedicel one-third longer than its greatest width; funicle 1 twice as long as wide, subequal to 5; 3 slightly the longest, 4-9 gradually shortening.

Habitat.—North Queensland: Cairns district (type), one female, two males in August and September (A.P.D.) ; Dunk Island, one male in August, H. Hacker.

Type.—South Australian Museum, *I. 11012.*

The male was originally described as a distinct species.

STYLOTELEIA NIGRICINCTA Dodd.

Trichoteleia nigricincta Dodd, Archiv fur Naturgeschichte, Berlin, vol. 80, (1915).

Female.—Length, 2.40 mm.

Head black; thorax rich orange-red, the median lobe of the scutum dusky; abdomen dull orange, dusky-black at base, apex, and along lateral margins, the basal horn bright orange; legs, including the coxæ, golden-yellow; antennæ golden-yellow, the club black.

Vertex between the eyes not as wide as in *acutiventris,* the lateral ocelli as far from the median ocellus as from each other; vertex from the median ocellus to the occiput with numerous rather small punctures bearing fine setæ; frons smooth, the upper frons with a few scattered punctures, and a line of punctures against the eye margins; cheeks striate and with numerous punctures, the upper cheeks showing impressed reticulation. Pedicel twice as long as its greatest width; funicle joints narrower than the pedicel, 1 as long as the pedicel, 2 shorter than 1 but twice as long as wide, 3 slightly shorter than 2, 4 plainly shorter than 3, 5 as wide as long; club 5-jointed, 1-4 each twice as wide as long, 1 rather small, 3 slightly the widest. Thorax one-half longer than its greatest width; median lobe of scutum with numerous small punctures, the lateral lobes with scattered punctures; parapsidal furrows separated posteriorly by one-half their length; scutellum with a few fine punctures, its posterior margin almost straight; propodeum at base on either side of the abdominal horn with a short blunt tooth. Forewings distinctly brownish; marginal vein hardly one-half as long as the long stigmal vein, the postmarginal two-thirds longer than the stigmal; basal and median veins represented by thick brown lines. Abdomen a little less than twice as long as the head and thorax united, four times as long as its greatest width; segment 1 as long as its posterior width, with a large stout horn projecting over the propodeum; 2 scarcely longer than 1; 3 as long as 2, three-fourths as long as wide; 4 two-thirds as long as 3; 5 two-thirds as long as 4; 6 somewhat longer than 4 and 5 united, the basal portion one-half as long as the narrow apical portion; 1 striate, its horn circularly striate at base, smooth for the most part; 2 rather finely irregularly striate and densely finely reticulate; 3 and 4 with the striæ less distinct and giving way to the reticulate sculpture, which is inclined to fail medially on 4; 5 and basal portion of 6 with a smooth median path, on either side weakly reticulate with a few punctures; apical portion of 6 with fine striæ and pubescence.

Male.—Unknown.

Habitat.—North Queensland: Cairns district, the type female in February, A. P. Dodd.

Type.—South Australian Museum, *I. 11109.*

Very similar to *acutiventris,* but smaller, the vertex narrower between the eyes and with more numerous punctures, the funicle joints more slender than the pedicel, the posterior margin of the scutellum not definitely concave, the striæ less strong on segments 1 and 2 of abdomen, and the marginal vein shorter in relation to the stigmal vein.

STYLOTELEIA TERRÆ-REGINÆ Dodd.

Trichoteleia terræ-reginæ Dodd, Archiv fur Naturgeschichte, Berlin, vol. 80, (1915).

Female.—Length, 3.10 mm.

Black, the sides of the thorax and the abdomen somewhat brownish; legs golden-yellow, the coxæ somewhat darker; antennal scape golden-yellow, the pedicel and funicle joints brownish-yellow, the club black.

Vertex between the eyes rather broad, the lateral ocelli nearer to the median ocellus than to each other; upper frons and vertex between the ocelli smooth with a very few scattered punctures; behind the ocelli to the occiput the punctures are rather dense; lower frons smooth, with a row of punctures against the eyes; cheeks with scattered punctures; lower cheeks and frons against the mouth with converging striæ. Pedicel twice as long as its greatest width; funicle joints scarcely narrower than the pedicel; 1 a little longer than the pedicel, 2-5 gradually shortening, 5 as wide as long; club stout, compact, 5-jointed, 1-4 each fully twice as wide as long. Thorax one-half longer than its greatest width; scutum with scattered punctures on the median lobe, the lateral lobes smooth; parapsidal furrows punctate, separated posteriorly by less than one-half their length; scutellum with a few punctures, its posterior margin definitely concave; carinæ on either side of propodeum not raised at base in the form of teeth. Forewings very lightly stained; marginal vein two-thirds as long as the long stigmal, the postmarginal one-half longer than the stigmal; basal and median veins marked by thick light brown lines. Abdomen twice as long as the head and thorax united, about five times as long as its greatest width; segment 1 fully as long as its posterior width, with a large stout horn projecting over the propodeum; 2 somewhat longer than 1; 3 as long as 2, as long as wide; 4 a little shorter than 3; 5 two-thirds as long as 4; 6 no longer than 4 and 5 united, the basal portion one-half as long as the apical portion; 1 strongly striate, its horn smooth but circularly striate at base; 2 and 3 rather strongly striate, rugulose between the striæ; 4 and 5 with similar sculpture but the striæ are weaker and the median line is almost smooth; basal portion of 6 smooth at the median line, on either side with dense punctures, the apical portion with fine striæ and pubescence.

Male.—Length, 2.45 mm.

Scutum and scutellum with the fine pubescent punctures rather more numerous than in the female; posterior margin of scutellum straight; propodeum longitudinally foveate medially, the teeth stout and blunt. Abdomen two-thirds longer than the head and thorax united; segments 4 and 5 not smooth at the median line; 4 with scattered punctures posteriorly; 5 with scattered punctures between the striæ;

6 shorter than 5, rather densely punctate and pubescent; 7 and 8 very short. Antennal scape and pedicel yellow, the basal flagellar joints suffused with yellow; funicle 3 slightly the longest, 1 twice as long as wide, 9 hardly shorter than 1.

Habitat.—North Queensland: Cairns district, two females, one male in February and September, A. P. Dodd.

Type.—South Australian Museum, *I. 11154.*

Distinguished from *acutiventris* and *nigricincta* by its colour, absence of teeth on the female propodeum, and the stronger striation of the abdomen, and from *nigricincta* by the concave posterior margin of the scutellum, width of the vertex between the eyes, and sparser punctuation between the ocelli.

PHŒNOTELEIA Kieffer.

Broteria, vol. 14, p. 62 (1916).

This peculiar genus was erected to contain one species, *P. rufa* Kieffer, from the Philippine Islands. The discovery of a congeneric species from North Queensland is, therefore, of considerable interest. This insect has the general habitus of *Baryconus* Foerster, but the basal abdominal horn or process is greatly lengthened, extending for some distance into the mesoscutum and fitting into a deep margined channel, which cuts through the propodeum, metanotum, and scutellum, so that these sclerites are visible only laterally; when viewed from the side the outline of this process is continuous with the thorax. The submarginal vein has the downward bend, characteristic of *Styloteleia* Kieffer and *Anteromorpha* Dodd. The carinæ on the propodeum appear to be the true lateral carinæ. The second abdominal segment is distinctly longer than the third and from lateral aspect is constricted at its base. The male of this genus is not yet known.

PHŒNOTELEIA CANALIS New Species.

Female.—Length, 3·70 mm.

Bright red-brown, the eyes and ocelli black, the abdomen dusky at apex; coxæ, trochanters, and femora bright yellow, the posterior coxæ and anterior femora brownish at base, the tibiæ and tarsi dusky-yellow; antennæ golden yellow, the club black.

Head from dorsal aspect less than twice as wide as long, the vertex posteriorly descending sharply to the occipital margin; from frontal aspect the head is circular; frons not depressed above the antennal insertion; cheeks broad; mandibles tridentate; eyes large, bare; ocelli large, close together, the lateral pair separated by their own diameter from the median ocellus and by less than one-half their own diameter from the eyes; head with fine pubescence, densely rather strongly reticulate-punctate and finely coriaceous, the sculpture with a transverse arrangement on lower half of frons; lower cheeks and the frons against the mouth with converging striæ. Antennal scape moderately long and slender, its articulate joint long and slender; pedicel almost twice as long as its greatest width; funicle joints as wide as the pedicel, 1 almost twice as long as the pedicel, 2 two-thirds as long as 1, 2-5 gradually shortening, 5 as long as wide; club rather slender, 5-jointed, joints 1-4 about subequal, each slightly wider than long. Thorax from dorsal aspect one-half longer than its greatest width; from lateral aspect about twice as long as high, flat above; pronotum narrowly visible on the sides; scutum almost as long as wide, broadly rounded anteriorly, strongly reticulate-punctate and with fine pubescence; parapsidal furrows absent; scutellum present on either side of median channel, its posterior margin straight, its surface coriaceous and with a few punctures; metanotum present on either side as a small transverse concave plate; propodeum long, on either side with a lateral carina running from its base somewhat obliquely inwardly to join the margin of the median channel before the posterior margin. Posterior femora distinctly swollen. Forewings long but not reaching apex of abdomen; moderately broad; ciliation normal; lightly stained brownish; submarginal vein joining the costa at slightly more than one-half the wing length, rather close to the costa except in its apical third where there is a distinct downward curve; marginal vein short, one-fourth as long as the stigmal which is long and oblique, the postmarginal twice as long as the stigmal; basal and median veins indicated by light brown lines. Abdomen, without its basal horn, one-half longer than the head and thorax united, four times as long as its greatest width; a little narrowed at base, narrowing to apex; segment 1 twice as wide as long, produced anteriorly to merge with its process, which is very long, reaching almost to the middle of the scutum, slender, from lateral aspect not raised but continuing the direction of the segment, separated posteriorly from the segment by an oblique carina on either side, these carinæ meeting sharply at the median line; 2 one-third longer than its greatest width, sharply impressed or constricted at base; 3 three-fifths as long as 2; 4 a little shorter than 3; 5 as long as 4; 6 slightly shorter than 5, conical, almost twice as long as its basal width; abdomen bluntly rigid medially; segment 1 with two or three striæ on either side, transversely rugose at base, smooth posteriorly, the horn finely transversely striate but coarsely transversely rugose posteriorly; 2-4 longitudinally striate, finely sculptured between the striæ which are absent medially on 3, 4, and posterior third of 2, where the surface bears fine impressed reticulation; 5 and 6 with scattered pubescent punctures and fine striæ which fail medially on 5.

Male.—Unknown.

Habitat.—North Queensland: Dunk Island, one female in August. H. Hacker.

Holotype.—In the Queensland Museum.

ANTEROMORPHA Dodd.

Royal Soc. of S. Australia, vol. 37, p. 145 (1913).

Female; Male.—Head from dorsal aspect twice as wide as long; occipital margin concave, the frontal outline gently convex from eye to eye; from lateral aspect the frons and vertex are gently convex, the vertex posteriorly shortly declivous to the occipital margin; frons broad, hardly impressed above the antennal insertion; cheeks broad; eyes moderately large, wide apart, lightly pubescent; ocelli wide apart, the lateral pair touching the eye margins; mandibles large, bidentate, the teeth long and acute; maxillary palpi 4-jointed. Antennæ 12-jointed in both sexes; in the female the funicle joints short, the club 6-jointed; in the male the flagellar joints submoniliform. Thorax from lateral aspect much longer than high, almost flat above; from dorsal aspect one-half longer than its greatest width; pronotum narrowly visible laterally; scutum stout, its anterior margin broadly rounded, somewhat declivous anteriorly; parapsidal furrows absent; scutellum rather large, its posterior margin faintly convex; metanotum triangular, bluntly pointed at apex, about as long as its basal width, somewhat shorter than the scutellum, projecting as a flat tooth over the propodeum as far as or a little beyond its posterior margin; propodeum rather short, without lateral carinæ, medially with a pair of well-separated carinæ which curve sharply to form the almost straight posterior margin, the posterior angles in the form of short teeth; mesopleura with a large impression; metapleura with a cross-furrow at half their length. Legs slender; posterior tarsi a little longer than their tibiæ, their basal joint hardly as long as 2-5 united. Forewings extending to apex of abdomen; moderately broad; marginal cilia moderately short, discal cilia fine and dense; submarginal vein in its distal third curving away from before joining the costa; marginal vein shorter than the stigmal, which is long and very oblique, the postmarginal somewhat longer than the stigmal; basal and median veins hardly marked. Abdomen a little longer than the head and thorax united, twice as long as its greatest width, a little narrowed at base, blunt at apex; segment 1 sub-sessile, transverse, without a prominence in the female; 2 plainly longer than 1; 3 much the longest, somewhat longer than 1 and 2 or 4-6 united.

Type.—*A. australica* Dodd.

Among the Australian genera, in *Lapitha* Ashmead the abdomen is more petiolate, and segments 2 and 3 are almost subequal; in *Opisthacantha* Ashmead the spine on the metanotum is simple, the abdomen is more petiolate, and the parapsidal furrows are complete; in *Chromoteleia* Ashmead the parapsidal furrows are complete, and segments 2 and 3 of the abdomen are subequal. I have been unable to reconcile *Anteromorpha* with any of the genera given by Kieffer (1926); its distinguishing characters may be found in the absence of parapsidal furrows, form of the metanotum, subsessile abdomen with its long third segment, downward curving submarginal vein, and very oblique stigmal vein.

The Hawaiian species, *Opisthacantha dubiosa* Perkins (Fauna Hawaiiensis, vol. 2, p. 623, 1910) will fall in this genus. I have seen an imperfect specimen, which is strikingly similar to *A. australica,* and may prove to be identical.

ANTEROMORPHA AUSTRALICA Dodd.

Royal Soc. of S. Australia, vol. 37, p. 146 (1913).
A. assimilis Dodd, ibidem, p. 146.

Female.—Length, 1·50–1·80 mm.

Head and thorax black; abdomen dull brown to brownish-black; legs golden-yellow, the coxæ sometimes brown; antennal scape yellow, dusky at apex, the funicle joints fuscous, the club black.

Head with a dense fine pale pubescence; vertex and upper two-thirds of frons with a dense fine reticulation which has a longitudinal tendency on the frons; against the occiput fine indistinct longitudinal striæ are present; lower third of face finely transversely striate above the antennal insertion, longitudinally striate on either side; cheeks striate below, reticulate above. Antennal scape moderately long, its articulate joint long; pedicel one-half longer than its greatest width; funicle joints as wide as the pedicel, 1 almost as long as the pedicel, one-third longer than wide, 2 quadrate, 3 and 4 small and transverse; club 6-jointed, joint 1 small and transverse, 2-5 each twice as wide as long. Scutum and scutellum finely densely pubescent and closely shallowly reticulate-punctate, the sculpture of the scutellum finer than that of the scutum; metanotum rugose. Forewing lightly or distinctly brownish; marginal vein one-third to two-thirds as long as the stigmal, the postmarginal hardly one-half longer than the stigmal. Segments 1 and 2 of abdomen strongly striate; 3 finely, somewhat irregularly, striate, finely sculptured between the striæ which are inclined to fail medially; lateral margins of abdomen pubescent; segments 2 and 3 each with a row of hairs posteriorly, 3 with a few hairs dorsally; 4-6 with numerous hairs and minute punctures.

Male.—Antennæ black, the scape yellow except at apex; pedicel slightly longer than its greatest width; funicle 1 distinctly longer than the pedicel, twice as long as wide; 3 a little shorter than 1; 2 plainly shorter than 1, a little shorter than 3; 4-9 subequal, moniliform, each a little longer than wide.

Habitat.—Queensland: Cooktown, Cairns, Pentland, Rockhampton, Brisbane, Toowoomba, and Chinchilla. New South Wales: Moonie River. A small series.

Type.—South Australian Museum, *I. 1383.*

A. assimilis Dodd is a true synonym, the wing characters being slightly variable.

A single female, labelled "Queensland, A. A. Girault," has the thorax yellowish brown, and probably represents a distinct species.

HOPLOTELEIA ASHMEAD.

Bull U.S. Nat. Museum, vol. 45, p. 227 (1893).

A world-wide genus containing 30-40 described species, the type, *H. floridana* Ashmead, from North America. Ashmead recognised the genus by the "three impressed lines on the mesonotum," and this character has since been generally accepted. However, in most of the Australian species, the median groove of the mesoscutum is not defined, or it may be replaced by a median carina, as in *H. orthopteræ* Dodd from West Africa, *H. serena* Dodd (*Camptoteleia carinata* Kieffer) from the Philippine Islands, and the species herein described as *H. elevata* Dodd.

The Australian species are very similar in size, colour, and sculpture, and their separation has not been readily accomplished. No reliable specific differences could be found in the wings or antennæ. The characters used to distinguish the species are mostly small, but appear to be valid. The colour of the legs and antennæ seems constant, although as a general rule I do not attach great importance to the colour of the appendages in the *Scelionidæ*.

The nine species recognised in this paper are from Eastern Australia, mostly from coastal or subcoastal districts; *H. amica,* and to a lesser degree *H. fœderata,* may be inland forms.

Hoploteleia grandis Dodd (Royal Soc. of S. Australia, vol. 37, p. 176, 1913) is not a member of this genus.

KEY TO THE AUSTRALIAN SPECIES OF *HOPLOTELEIA* ASHMEAD.

1.	Mesoscutum with a median carina; occipital margin not uniformly concave	*elevata* new species.
	Mesoscutum without a median carina; occipital margin uniformly concave	2.
2.	Metanotum with one small tooth; femora black; mesoscutum with a distinct median groove; hind tarsi much longer than their tibiæ	*atricornis* Dodd.
	Metanotum bidentate; femora red	3.
3.	Hind tarsi much longer than their tibiæ; median groove of scutum rather well marked	*persimilis* Dodd.
	Hind tarsi not much longer than their tibiæ; median groove of scutum not defined	4.
4.	Females	5.
	Males	10.
5.	Apical abdominal segment with a spine on either side ..	6.
	Apical segment without spines or teeth	8.
6.	Antennæ almost wholly black; apical spines of abdomen long	*australica* Dodd.
	Funicle joints bright red; apical teeth short	7.
7.	Frontal impression sharply rounded above; coxæ red ..	*sculpturata* Dodd.
	Frontal impression broadly rounded above; coxæ black	*amica* new species.
8.	Antennæ wholly black	*gracilicornis* Dodd.
	Scape and funicle joints red	9.

9.	Segments 3–5 of abdomen not definitely striate; cheeks largely smooth	*pulchricornis* Dodd.
	Segments 3–5 very definitely striate; cheeks densely sculptured	*fœderata* new species.
10.	Apical spines of abdomen long	*australica* Dodd.
	Apical spines short or absent	11.
11.	Cheeks largely smooth; coxæ red	*pulchricornis* Dodd.
	Cheeks densely sculptured	12.
12.	Coxæ black; abdomen much narrower than the thorax	*amica* new species
	Coxæ red; abdomen not much narrower than the thorax	*fœderata* new species.

HOPLOTELEIA AUSTRALICA Dodd.

Royal Soc. of S. Australia, vol. 37, p. 133 (1913).
H. insularis Dodd, ibidem, p. 134.

Female.—Length, 2·50–3·00 mm.

Black; tegulæ red; coxæ black, the legs bright reddish-yellow; antennæ black, the scape and funicle joints sometimes suffused with brown.

Head from dorsal aspect not more than twice as wide as long, slightly wider than the thorax; from lateral aspect the vertex flat, hardly sloping to the occipital margin; vertex coarsely longitudinally rugose-punctate; frons below the anterior ocellus shallowly reticulate-punctate; along the eye margins from just behind each lateral ocellus to the frontal depression there is fine close scaly reticulation; frontal depression strongly margined, large, longer than wide, sharply convex above, narrowly separated above from the eyes, smooth but showing obscure cross-striæ; frons on either side of depression shallowly reticulate-punctate; cheeks coarsely reticulate-punctate, the sculpture shallow toward the mouth; lateral ocelli a little separated from the eyes, distant from the frontal ocellus by less than 1½ times their own diameter; one or two irregular oblique striæ connect the frontal and lateral ocelli; head with a sparse pubescence of fine pale hairs. Antennal scape long and slender, the articulate joint very short; pedicel one-half longer than its greatest width; funicle 1 a little longer than the pedicel, twice as long as its greatest width, 2 shorter than 1, 3 a little longer than wide, 4 as wide as long; club slender, not well differentiated, joint 1 wider than long, much shorter than 2 which is longest and as long as wide, 3-5 each slightly wider than long. Thorax from dorsal aspect one-fourth longer than its greatest width; from lateral aspect one-third longer than high; pronotum narrowly visible on the sides, strongly rugose-punctate and with long white hairs; scutum three-fourths as long as its greatest width, its anterior margin strongly convex, its surface with scattered hairs; parapsidal furrows deep, punctate, at either end terminating in a large puncture; median lobe of scutum at the median line with confluent punctures which are shallow and indefinite anteriorly and do not form a groove, the rest of the surface and the parapsides faintly wrinkled and with dense fine impressed reticulation; between the posterior ends of the parapsidal furrows are two or three larger punctures; parapsides with two or three large punctures along anterior margin and a punctate sulcus along lateral margin; scutellum strongly reticulate-punctate; metanotum coarsely foveate, the median process excavated medially and bounded by a straight raised carina, the posterior margin between the ends of these carinæ almost straight, the lateral margins oblique; propodeum short, its posterior margin uniformly gently concave, shallowly punctate and pubescent laterally, foveate medially, the lateral carinæ short and straight. Posterior tarsi not much longer (8:7) than their tibiæ. Forewings reaching apex of abdomen; subhyaline or lightly tinted; venation bright yellow; marginal vein short, not more than one-fourth as long as the stigmal, which is long and slightly oblique, the postmarginal three times as long as the stigmal. Abdomen as long as the head and thorax united, 2½ times as long as its greatest width; segment 1 two-thirds as long as its basal width; 2 one-third longer than 1; 3 one-third longer than 2, a little shorter than 4-6 united; 4 one-half as long as 3; 6 short, transverse, armed on either side with a sharp spine, the blunt apex showing just below; 1 with eight strong complete striæ, at base the surface between the striæ deeply pitted, posteriorly the surface finely sculptured and with a few fine short striæ; 2 rather strongly striate, the striæ somewhat irregular, finely sculptured between, laterally with obscure punctures between; 3 more finely and closely striate and with obscure shallow punctures between; punctuation more distinct on 4, the striæ faint; 5 for the most part with fine impressed reticulation, but indefinite punctures are present also; 6 densely punctate; lateral margins of abdomen and posterior margin of 2-4 with fine impressed reticulation; abdomen, except basal segment, with a conspicuous pubescence of fine white hairs which are longer laterally and on the apical segments.

Male.—Antennæ black, the scape and pedicel deep dusky-brown; pedicel small, no longer than its greatest width; flagellar joints filiform, 1 almost twice as long as its greatest width, 2 and 3 hardly shorter than 1, 4 plainly shorter than 3 and one-third longer than wide, 4-9 subequal. In structure and sculpture resembling the female.

Habitat.—North Queensland: Thursday Island, Cairns, Pentland; a series. This species is common in the Cairns district.

Type.—South Australian Museum, *I. 1363.*

HOPLOTELEIA AUSTRALICA VAR. *OCCIDENTALIS* DODD.

Royal Soc. of Queensland, vol. 26, p. 96 (1914).

Male.—Length, 2·65 mm.

Differs from the typical form in the colour of the antennæ, the scape being bright golden-yellow, the pedicel and basal flagellar joints suffused with yellow.

Female.—Unknown.

Habitat.—North-West Queensland: Cloncurry, one male in April, A. P. Dodd.

Type.—In the South Australian Museum.

HOPLOTELEIA ATRICORNIS Dodd.

H. nigricornis Dodd, Royal Soc. of S. Australia, vol. 37, p. 134 (1913); (preoccupied by *H. nigricornis* Cameron, 1912).

H. atricornis Dodd, Ent. Soc. of London, p. 341 (1919).

Female.—Length, 2·60 mm.

Black; tegulæ black; coxæ black, the femora piceous, the tibiæ and tarsi golden-yellow; antennæ wholly black.

Head from dorsal aspect less than twice as wide as long; vertex hardly sloping to the occipital margin; vertex behind the line of the lateral ocelli strongly longitudinally rugose-punctate; upper frons except medially and around the ocelli with fine dense impressed reticulation; there are about four striæ from the anterior ocellus to the frontal impression; frons on either side of the impression shallowly reticulate-punctate; cheeks with fine dense impressed reticulation. Antennæ as in *australica*. Thorax a little narrower than the head, one-third longer than its greatest width; pronotum distinctly visible on the sides, very strongly striate; scutum with fine dense impressed reticulation and faint wrinkles, the median lobe with a complete punctate median groove whose margins are carinate; a few weak punctures occur against the posterior margin of the median lobe; scutellum coarsely reticulate-punctate; metanotal plate small, forming an upright triangular tooth, not bidentate; propodeum as in *australica*, the posterior margin uniformly gently concave. Posterior tarsi one-half longer than their tibiæ. Forewings lightly stained; marginal vein one-fourth as long as the long stigmal vein, the postmarginal three times as long as the stigmal. Abdomen no longer than the head and thorax united; a little more than twice as long as its greatest width; segment 3 two-thirds longer than 2, as long as 1 and 2 united, a little longer than 4-6 united; 6 on either side with a short sharp spine; 3 densely finely irregularly striate and with shallow indefinite punctures between the striæ; 4 and 5 with close fine impressed reticulation, 4 with also very fine striæ and traces of shallow punctures.

Male.—Length, 2·50 mm.

Antennæ wholly black, as in *australica*.

Habitat.—North Queensland: Cairns district, one female (type) in December; Herbert River, one pair in March.

Type.—South Australian Museum, *I. 1365*.

Readily distinguished by the dark femora and tegulæ, pronounced median groove of the scutum, long tarsi, and the tooth of the metanotum not being bidentate.

This species appears identical with a Philippine Island species which is probably *H. pacifica* Ashmead. I have before me three females from that locality; one was received from the U.S. National Museum and is labelled *Hoploteleia pacifica* Ash., as identified by Mr. A. B. Gahan.

The remaining two were received from Professor C. F. Baker, of Los Banos, Philippine Islands, and are labelled *Hoploteleia philippinensis* Kieffer, possibly by Kieffer himself; they represent two species, one of which, to judge from Kieffer's description, is correctly determined; the other specimen, which represents the same species as the National Museum example, agrees with the description of *H. unidens* Kieffer. Thus it would appear that both *unidens* Kieff. and *atricornis* Dodd are synonyms of *pacifica* Ashm. However, Ashmead's description of *pacifica* does not agree with the National Museum example, and, although Mr. Gahan's determination is probably correct, the doubt that exists justifies the retention of the name *atricornis* for the time being.

HOPLOTELEIA PERSIMILIS Dodd.

Royal Soc. of Queensland, vol. 26, p. 96 (1914).

H. aureiscapus Dodd, ibidem, p. 96.

Female.—Length, 2·60–3·00 mm.

Black, tegulæ red; legs golden-yellow, the coxæ reddish yellow; antennal scape reddish-yellow, the pedicel and funicle joints suffused with brown, the club black.

Head from dorsal aspect not more than twice as wide as long; from lateral aspect the vertex sloping gently to the occipital margin; vertex and upper frons with fine impressed reticulation and shallow depressions indicating large punctures; posteriorly the vertex is coarsely reticulate- or rugose-punctate with a longitudinal tendency; lateral ocelli distant from the anterior ocellus by no more than $1\frac{1}{2}$ times their own diameter and connected with it by one or two oblique striæ; a short carina connects the anterior ocellus with the frontal depression which is sharply convex above; frons on either side of the depression reticulate-punctate, but smooth ventrally; cheeks coarsely reticulate-punctate and with fine impressed reticulation, and toward the mouth with several strong irregular striæ. Antennæ as in *australica*. Scutum with fine close impressed reticulation and shallow wrinkles, the median groove represented by a complete row of confluent punctures, and there are a few punctures on either side against the posterior margin; scutellum strongly confluently or reticulate-punctate; posterior margin of metanotal process concave, so that the two carinæ project in the form of teeth; propodeum foveate medially, densely punctate and pubescent laterally, its posterior margin uniformly gently concave. Posterior tarsi one-half longer than their tibiæ. Forewings lightly stained; marginal vein one-third as long as the long stigmal, the postmarginal three times as long as the stigmal. Abdomen slightly longer than the head and thorax united, almost three times as long as its greatest width; segment 3 two-thirds longer than 2, as long as 1 and 2 or 4-6 united; spines on either side of 6 short and acute; sculpture as in *australica*, except that the punctures between the striæ on segment 3 are more distinct; pubescence as in *australica*.

Male.—Coxæ dark, at least at base; spines at apex of abdomen long and slender. Antennal scape red, dusky toward apex, the pedicel dusky, the flagellum black; segmentation as in *australica.*

Habitat.—North Queensland: Herbert River (type), Innisfail, Cairns; four females, two males.

Type.—South Australian Museum, *I. 11009.*

The sexes were originally described as distinct species. At once differing from *australica* in the long posterior tarsi. The median punctures of the scutum are more in the form of a groove than in *australica,* the apical spines of the abdomen are shorter in the female, the concave posterior margin of the metanotal process gives a more apparent bidentate effect, and segment 3 of the abdomen is relatively longer.

HOPLOTELEIA GRACILICORNIS Dodd.

Royal Soc. of Queensland, vol. 26, p. 97 (1914).

Female.—Length, 2·75–3·25 mm.

Black, the tegulæ red; legs, including the coxæ, bright reddish-yellow; antennæ wholly black.

Head from dorsal aspect twice as wide as long, the vertex hardly sloping to the occiput; behind the ocelli the vertex is very strongly reticulate- or rugose-punctate with a longitudinal tendency; between the ocelli are three or four striæ or rugæ; upper frons shallowly reticulate-punctate medially, with fine impressed reticulation laterally; cheeks coarsely reticulate-punctate and with fine reticulation also; antennal impression narrowly rounded above. Antennæ as in *australica.* Thorax scarcely as wide as the head, one-fourth longer than its greatest width; scutum with fine close impressed reticulation and shallow wrinkles or depressions suggesting punctures, the median lobe with large confluent punctures toward posterior margin, along the median line, and against the anterior margin; scutellum with large confluent punctures; metanotal plate faintly bidentate, the carina forming the teeth close together; posterior margin of propodeum faintly concave with a slight projection at the junction of the lateral carinæ. Forewings reaching apex of abdomen; subhyaline; venation bright yellow; marginal vein one-fourth as long as the stigmal, the postmarginal 2½ times as long as the stigmal. Posterior tarsi scarcely longer than their tibiæ; posterior femora not much swollen. Abdomen no longer than the head and thorax united, hardly more than twice as long as its greatest width; segment 3 one-third longer than 2, as long as 4-6 united, somewhat shorter than 1 and 2 united; 6 before apex faintly truncate, without a spine or tooth on either side; 2 strongly irregularly striate, sculptured between the striæ but without definite punctures; 3 with large shallow punctures and fine indefinite striæ; 4 with similar but finer sculpture; 5 with fine impressed reticulation and numerous shallow punctures; 6 with fine reticulation.

Male.—Unknown.

Habitat.—New South Wales: Glen Innes, A. M. Lea (type). Queensland: Mount Tambourine and Cairns, A. P. Dodd. Three females.

Type.—In the collection of the Government Entomologist of New South Wales.

Differs from *sculpturata* in the less swollen hind femora, colour of antennæ, absence of spines at apex of abdomen, and less noticeable punctuation of segment 2 of abdomen; from *australica* in the colour of the coxæ, absence of spines at apex of abdomen, more definite punctuation and less definite striation of segment 3 of abdomen.

HOPLOTELEIA SCULPTURATA Dodd.

Royal Soc. of Queensland, vol. 26, p. 95 (1914).

Female.—Length, 3·75 mm.

Black, the tegulæ red; legs, including the coxæ, bright reddish-yellow; first three funicle joints clear reddish-yellow, the scape and pedicel dusky-red or almost black.

Head from dorsal aspect about 2½ times as wide as long, the vertex flat, not sloping to the occipital margin; vertex behind the line of the lateral ocelli very strongly reticulate- or rugose-punctate with a longitudinal tendency; upper frons with shallow depressions and close fine impressed reticulation; between the ocelli and on the upper frons are a few irregular striæ or rugæ; cheeks coarsely reticulate-punctate except for a small smooth area ventrally; frontal impression very sharply rounded above, smooth, without definite striæ. Antennæ as in *australica*. Thorax about one-fourth longer than its greatest width, scarcely as wide as the head; scutum with fine close impressed reticulation and shallow wrinkles or depressions suggesting punctures, the median lobe broadly confluently punctate posteriorly, this sculpture continued forward narrowly for its entire length but not forming a groove; against the anterior margin are close punctures; scutellum strongly reticulate-punctate; metanotal plate large, obtuse and faintly bidentate posteriorly, the two carinæ or teeth close together; posterior margin of propodeum almost straight, with a short blunt projection at the junction of the lateral carinæ. Posterior tarsi slightly longer than their tibiæ (7:6); posterior femora considerably swollen. Forewings reaching apex of abdomen; marginal vein one-fourth as long as the long stigmal, the postmarginal 2½ times as long as the stigmal. Abdomen no longer than the head and thorax united, twice as long as its greatest width; segment 3 two-thirds longer than 2, a little shorter than 1 and 2 united, as long as 4-6 united; 6 with an apical truncate carina armed at either side with a short spine or tooth; 2 strongly sparsely striate, medially with large shallow punctures between the striæ, laterally the punctures are coarse and distinct; 3 with large shallow confluent punctures and with fine irregular indefinite striæ; 4 with fine punctures, the striæ hardly discernible; 5 with fine impressed reticulation and numerous punctures; 6 rugose-punctate.

Male.—Unknown.

Habitat.—New South Wales: Tweed River, one female (type) in May, A. P. Dodd. North Queensland: Dunk Island, one female in August, H. Hacker.

Type.—South Australian Museum, *I. 11007.*

The punctuation of segments 2 and 3 of the abdomen is much stronger than in *australica.* The posterior femora are more noticeably swollen than in any of the known Australian species.

HOPLOTELEIA ELEVATA New Species.

Female.—Length, 3·20 mm.

Black, the tegulæ red; legs, including the coxæ, bright reddish-yellow; antennal scape red, the pedicel dusky, the funicle joints faintly suffused with red.

Head from dorsal aspect not more than twice as wide as long, the vertex not descending to the occiput, slightly wider than the thorax; occipital margin not uniformly concave, broadly straight or truncate medially and angled laterally; highly polished; behind the ocelli to the occiput are strong sparse irregular longitudinal rugæ or striæ, between which are large shallow indefinite punctures; between the ocelli is a very large triangular puncture; upper frons with shallow indefinite reticulate punctures; on either side of the anterior ocellus and narrowly behind the lateral ocelli is fine impressed reticulation; cheeks with longitudinal rows of confluent punctures; frontal impression acutely rounded above. Antennæ slender; funicle 1 one-half longer than the pedicel, three times as long as its greatest width; 3 very distinctly longer than wide; 4 as long as wide; club 1 somewhat wider than long, 2 a little longer than wide, 3-5 each as wide as long. Thorax from dorsal aspect one-third longer than its greatest width, from lateral aspect one-half longer than high; median lobe of scutum with a complete median carina, on either side strongly transversely rugose or irregularly striate, the lateral lobes shallowly reticulate-punctate; narrowly on either side of the parapsidal furrows is fine impressed reticulation; scutellum coarsely reticulate-punctate; posterior margin of metanotal plate concave and bidentate, the median carinæ well apart and a little divergent; posterior margin of propodeum definitely concave, the blunt projections well marked. Posterior femora somewhat swollen; posterior tarsi slightly longer than their tibiæ. Forewings slightly infuscate; marginal vein one-third as long as the stigmal, the postmarginal slightly more than twice as long as the stigmal. Abdomen no longer than the head and thorax united, $2\frac{1}{2}$ times as long as its greatest width; segment 3 two-thirds longer than 2, almost as long as 1 and 2 united; 6 on either side with a stout spine; 2 strongly striate, between the striæ almost smooth; 3 finely densely irregularly striate and densely punctate, the punctures of moderate size or very small; 4 with fine striæ and dense fine punctures, the median line and posterior margin with fine reticulation; 5 with fine impressed reticulation and scattered punctures; 6 with fine reticulation.

Male.—Antennæ black, the scape red, the pedicel dusky; funicle 2 as long as 1 or 3. Segments 4-6 of abdomen with fine reticulation and scattered punctures which are more numerous on 4; apical spines longer than in the female.

Habitat.—North Queensland: Cairns and Innisfail, one female, two males, in November and December, A. P. Dodd.

Holotype and *Allotype* in the Queensland Museum.

Paratype in the author's collection.

At once distinguished by the median carina and transverse rugæ of the median lobe of the mesoscutum, and the shape of the occipital margin.

HOPLOTELEIA PULCHRICORNIS Dodd.

Royal Soc. of S. Australia, vol. 37, p. 134 (1913).

H. acuminata Dodd, ibidem, p. 177.

Female.—Length, 3·25 mm.

Black; tegulæ red; legs, including the coxæ, and first six antennal joints bright golden- or reddish-yellow.

Head from dorsal aspect a little more than 2½ times as wide as long, no wider than the thorax; vertex sloping rather sharply to the occipital margin; vertex behind the ocelli strongly reticulate-punctate, toward the occiput longitudinally rugose-punctate; between the ocelli are several connecting striæ; upper frons medially shallowly reticulate-punctate, on either side with fine impressed reticulation; cheeks very narrow above, the ventral half for the most part smooth with a few punctures and obscure grooves; frontal impression rather broadly rounded above, without definite cross-striæ, but with oblique striæ laterally. Antennæ as in *australica.* Thorax one-fifth longer than its greatest width; scutum with shallow depressions or obscure punctures and close fine impressed reticulation; against the posterior margin of the median lobe with large confluent punctures, with smaller less distinct punctures against its anterior margin, and obscure punctures along the median line; parapsidal furrows separated posteriorly by one-half their length; scutellum strongly confluently punctate; metanotal process bluntly bidentate, the teeth well-separated, the posterior margin concave, the median carinæ diverging from base; posterior margin of propodeum slightly concave, faintly projecting at the junction of the lateral carinæ; metapleura strongly striate in centre. Posterior femora not much swollen; posterior tarsi no longer than their tibiæ. Forewings subhyaline or faintly yellowish; venation bright yellow; marginal vein one-fourth as long as the long stigmal vein, the postmarginal 2½ times as long as the stigmal. Abdomen a little (about one-sixth) longer than the head and thorax united, two and one-third times as long as its greatest width; segment 3 about one-fourth longer than 2, three-fourths as long as 1 and 2 united; 6 as long as 5, without a truncate plate or spines, pointed at apex; 2 with rather distinct punctures between the striæ, the punctures very distinct laterally; 3 confluently punctate and with fine indistinct or indefinite striæ; 4 with similar finer sculpture but medially with fine impressed reticulation and scattered punctures; 5 with fine impressed reticulation and numerous punctures; 6 with fine reticulation and fine indefinite punctures.

Male.—Antennal scape yellow, the pedicel brownish-yellow, the basal flagellar joints suffused with yellow.

Habitat.—Queensland: Cairns district (type), Bowen, Biggenden, Blackall Range, Brisbane, Mount Tambourine; a small series.

Type.—South Australian Museum, *I. 1366.*

In this species the head is more transverse than usual and descends noticeably to the occiput. The absence of apical teeth on the abdomen is found in *gracilicornis* and *fœderata;* in the former the antennæ are wholly black, while the distinguishing characters of *fœderata* are given later.

The sexes were originally described as distinct species. This species is parasitic on the eggs of a large *Tettigoniid* (*Orthoptera*).

HOPLOTELEIA FŒDERATA New Species.

Female.—Length, 3–3·50 mm.

Black; tegulæ red; legs, including the coxæ, bright reddish-yellow; antennal scape and first three funicle joints bright reddish-yellow, the pedicel fuscous.

Head from dorsal aspect a little wider than the thorax, a little more than twice as wide as long, the vertex not descending to the occiput; vertex strongly reticulate-punctate without a longitudinal tendency; behind each lateral ocellus and laterally on the upper frons with close fine impressed reticulation; between the ocelli are two or three connecting striæ; upper frons reticulate-punctate; frontal impression very broadly rounded above, more or less transversely striate; cheeks very strongly reticulate- or rugose-punctate. Antennæ normal. Thorax a little longer than its greatest width; scutum with fine close impressed reticulation and shallow depressions or obscure punctures, with large confluent punctures posteriorly on the median lobe, and smaller punctures against the anterior margin of the median lobe; scutellum with large confluent punctures; metanotal plate concave and bluntly bidentate at apex, the median carinæ diverging from base; posterior margin of propodeum faintly concave, with a blunt projection at the lateral carinæ. Legs spiny; posterior femora somewhat swollen; posterior tarsi no longer than their tibiæ or a little shorter. Forewings reaching apex of abdomen; subhyaline or faintly yellowish; marginal vein one-third as long as the stigmal, the postmarginal three times as long as the stigmal. Abdomen a little (about one-sixth) longer than the head and thorax united, two and one-third times as long as its greatest width; segment 3 plainly shorter than 1 and 2 united, one-fourth longer than 2; 6 about as long as 5, acuminate, without apical teeth; 2 very strongly striate, hardly sculptured between the striæ medially, with obscure punctures laterally; 3 quite strongly striate, with shallow punctures between; 4 and 5 with finer striæ, which are still dense and distinct, the punctures more definite on 5, the median line narrowly smooth except for a few punctures; 6 with numerous punctures and fine impressed reticulation.

Male.—Antennal scape red, the basal funicle joints and the pedicel a little suffused with red. Abdomen not much narrower than the thorax (5:4), 2½ times as long as its greatest width, the punctuation of segments 3-5 more distinct than in the female; apical segment gently concave at apex and with a small obtuse tooth on either side.

Habitat.—Queensland: Chinchilla, twelve females, eleven males, January-March, A. P. Dodd; Westwood, one pair in March, A. P. Dodd.

Holotype and *Allotype* in the Queensland Museum.

Paratypes in the author's collection.

Very closely related to *pulchricornis*, from which it may be distinguished by the densely sculptured cheeks, very definite striæ of segments 3-5 of abdomen, more spiny legs, and somewhat swollen hind femora. In *sculpturata* the scape is darker than the funicle joints, the metanotum is less evidently bidentate, the female abdomen is bispinose at apex, and the hind femora are much swollen. In *amica* the coxæ are black, the shallow punctures of the mesoscutum are hardly discernible, the posterior margin of the propodeum is more concave with the projections more definite, the female abdomen is bispinose at apex, and the male abdomen is more slender.

HOPLOTELEIA AMICA New Species.

Female.—Length, 3·25–3·50 mm.

Black, the tegulæ red; legs bright reddish-yellow, the coxæ black, the tarsi dusky; first five antennal joints reddish-yellow, the pedicel sometimes dusky.

Head from dorsal aspect a little more than twice as wide as long, a little yet distinctly wider than the thorax; vertex hardly descending to the occiput; vertex and upper frons coarsely reticulate-punctate without a longitudinal tendency; between the ocelli are about two connecting striæ; behind the lateral ocelli and on either side of the upper frons is fine impressed reticulation; frontal impression very broadly rounded above, shining, without definite striæ; cheeks coarsely reticulate-punctate. Antennæ normal. Thorax a little longer than its greatest width; scutum with fine close impressed reticulation and finely wrinkled, the median lobe with large confluent punctures posteriorly and smaller confluent punctures against the anterior margin; scutellum coarsely confluently punctate; metanotal plate deeply concave and plainly bidentate posteriorly, the median carinæ wide apart and parallel; posterior margin of the propodeum distinctly concave medially, with a strong blunt projection at the junction of the lateral carinæ. Posterior femora a little swollen; posterior tarsi slightly longer (6 : 5) than their tibiæ. Forewings reaching apex of abdomen; subhyaline; venation fuscous; marginal vein one-third as long as the stigmal, the postmarginal almost three times as long as the stigmal. Abdomen no longer than the head and thorax united, slightly more than twice (20 : 9) as long as its greatest width; segment 3 two-thirds longer than 2, almost as long as 1 and 2 united; 6 before the apex truncate and armed on either side with a short sharp spine; 2 strongly striate, hardly sculptured between the striæ except laterally; 3 densely rather finely irregularly striate and with shallow obscure punctures between; 4 with similar finer sculpture, the punctures more distinct on 5; 6 reticulate-punctate.

Male.—Antennæ black, the scape red, the pedicel suffused with red. Abdomen distinctly narrower (2 : 3) than the thorax, two and two-thirds as long as its greatest width; apical segment broadly truncate and with a short tooth on either side.

Habitat.—South Queensland: Chinchilla, 14 females, 1 male January-March, A. P. Dodd; Goondiwindi, three females, two males in January, A.P.D. New South Wales: Warialda, one female in January.

Holotype and *Allotype* in the Queensland Museum.

Paratypes in the author's collection.

The shallow depressions or obscure punctures of the scutum are much less evident than in *sculpturata, pulchricornis,* and *fœderata,* while the projections of the posterior margin of the propodeum are more pronounced. Differs from the female of *fœderata* in the smooth frontal impression, black coxæ, and the presence of the short apical spines on the abdomen; from *sculpturata* in the normal hind femora, black coxæ, and broadly rounded frontal impression; from *pulchricornis* in the black coxæ, apical spines of abdomen, and densely sculptured cheeks.

The Location of Saponin in the Foam-bark Tree (*Jagera pseudorhus*).

By W. D. Francis, Assistant Government Botanist.

Plates I. and II.

(*Read before the Royal Society of Queensland, 25th June, 1928.*)

I. Introduction.
II. Methods.
III. The location of saponin in the stem and branchlets.
IV. The location of saponin in the root.
V. The location of saponin in the walls of the fruit.
VI. The location of saponin in the leaflets.
VII. The location of saponin in the young twigs.
VIII. Interpretation of results.
IX. The function of saponin in the species.
X. Summary.

I.—Introduction.

The bark of *Jagera pseudorhus* was a commercial commodity in Australia during the war. It was used as a substitute for quillaja bark, which produces a ''head'' or foam on cordials. The utilisation of the local product was due in a great measure to the enterprise of the Forestry authorities of Queensland, who at the time constituted a section of the Department of Public Lands. Mr. C. J. Trist, the Secretary of the present Provisional Forestry Board of Queensland, informed the writer that about 9 tons of the bark of the species were collected and disposed of to brewers and cordial manufacturers. Owing to the scattered distribution of the trees, which increased the cost of collection, the demand for the bark has discontinued in recent years. In a report [12] published in 1919, Mr. E. H. F. Swain, then Director of Forests, states that a sample of the bark of *Jagera pseudorhus*, which was submitted to the Government Analyst, was found to contain 6·9 per cent. of saponin.

R. Hamlyn-Harris and F. B. Smith [7] investigated the poisonous action on fish of infusions of the bark, which was known to be used by the aborigines in procuring fish for food. Hamlyn-Harris and Smith found that the bark contained saponin, and is a rapid and powerful piscicide, producing death in concentration of 1:1000. They also ascertained that frothing of an infusion of the bark took place at a dilution of 1: 10000, and hæmolysis of blood corpuscles at a concentration of 1:14000. The leaves were found by them to be free of saponin. The toxic effect on fish and the hæmolytic property of the saponin as demonstrated by these authors indicate that the use of the bark in the manufacture of cordials may not be advisable.

The foam-bark tree is more familiarly known in a technical sense under A. Richard's name of *Cupania pseudorhus*. The species was transferred to the genus *Jagera* by L. Radlkofer, who applied himself to the study and revision of the Sapindaceæ. As Radlkofer's nomenclature appears to be accepted by very many systematists, his combination *Jagera pseudorhus* is adopted in this paper. It is regrettable that the name which is more familiar locally has in consequence to be regarded as a synonym.

In habit of growth the foam-bark tree is not a large species. It is a rain-forest tree. So far as the writer has observed it in subtropical rain forests, it does not exceed about 60 feet in height and 12 inches in stem diameter. When growing in the open the trees produce a dome-shaped head of foliage and a short stem. Generally the species is sparsely distributed. F. M. Bailey [1] states that it ranges in Queensland from the Brisbane River to the Barron River Ranges of North Queensland. According to Bentham [2] it occurs as far south as the Hastings River in New South Wales. These locality records show that it ranges from 17 deg. S. to 32 deg. S. It is not found far inland from the coast and coastal ranges. It is confined to Australia.

The properties of saponins and their distribution in the plant kingdom are outlined by Greshoff [5], Kobert [8], Haas and Hill [6], Molisch [10], and Czapek [4]. J. H. Maiden [9] has also published some notes on saponins and their occurrence in Australian plants. It is observed by Kobert that such a wide distribution in the plant kingdom as that of saponins is possessed only by the essential oils. Kobert and Haas and Hill state that all saponins when treated with strong sulphuric acid exhibit red or violet colours. According to the authors quoted above, the saponins may be briefly described as nitrogen-free glucosides which on hydrolysis yield sugars such as glucose, galactose, arabinose, and rhamnose, together with other substances termed sapogenins whose constitution is unknown; they are amorphous and colloidal.

Molisch [10, p. 196] quotes Greshoff to the effect that saponins in barks and in the rind of fruits act as protective substances, and in seeds and roots serve as reserve materials. Molisch also points out that the location of saponins is not known in most plants, and that it is therefore desirable that someone should investigate microchemically their occurrence in the cells and tissues of the numerous unstudied plants.

F. Czapek [4] includes the saponins under the chapter heading of little known, omnicellularly distributed, nitrogen-free end-products of plant metabolism. He states [4, p. 527] that, according to the microchemical investigations of Rosoll and Hanausek, saponin occurs in solution in the cell sap, principally in the parenchyma cells of bark, wood and medullary rays. Further on [4, p. 535] he remarks that different saponin bodies probably occur in the Sapindaceæ.

II.—Methods.

In locating saponin in various parts of the plant four properties of saponin were utilised: (1) the production by shaking of a foam on the surface of the solution obtained by steeping saponin-containing tissues in distilled water; (2) the production of a reddish-violet colour on treatment of sections with equal parts of concentrated sulphuric acid and absolute alcohol; (3) the insolubility of almost all saponins in absolute alcohol; (4) the solubility of most saponins in water. The treatment with concentrated sulphuric acid and absolute alcohol is a modification of a method adopted by Hanausek and outlined by Molisch [10, p. 196]. In addition to the application of sulphuric acid and alcohol Hanausek finally added ferric chloride, which in the presence of saponins turned the reddish-violet colour to brown or brownish blue. The writer was unable to obtain this final colour reaction with ferric chloride either in the saponin-containing sections or in the solutions of saponin contained in test tubes.

This colour test with ferric chloride is apparently not universally applicable to saponins, as Haas and Hill [6, p. 165] state that concentrated sulphuric acid containing a little ferric chloride gives with many saponins a blue or bluish-green colour or fluorescence. The application of concentrated sulphuric acid alone to sections of the tissues was not found satisfactory. The action of the concentrated acid partly destroyed the tissues on account of its solvent action on cellulose. It also converted the greater part of the sections to a reddish-brown colour and produced numerous gas inclusions which made observation of the tissues difficult.

The addition to the concentrated acid of an equal volume of absolute alcohol as used by Hanausek produced a very useful testing combination which gave good results. Sections of those tissues which showed positive reactions with the concentrated sulphuric acid and alcohol were also submitted to a solubility test by heating them in distilled water, and another series of sections of the same tissues was subjected to an insolubility test by treatment with absolute alcohol. The sections were then tested with the sulphuric acid-alcohol combination. If they gave positive reactions in the cases in which they were treated with absolute alcohol and negative reactions in the instances in which they were heated in water, the results were regarded as confirmatory.

III.—The Location of Saponin in the Stem and Branchlets.

Small pieces of the fresh bark of the stem of a large tree which were steeped in distilled water produced abundant frothing when shaken. The froth was immediately dispersed by the addition to the liquid of a few drops of alcohol. The dispersive effect of alcohol and ether on saponin froth is mentioned in the British Pharmaceutical Codex [3]. Sections of the bark of the stem on treatment with the sulphuric acid-alcohol combination developed the reddish-violet colour in the walls of many of the sclerenchyma cells and in the walls of many of the bast fibres and parenchyma cells in the outer part of the phloem.

There is a continuous but often very uneven ring of sclerenchyma in the bark of *Jagera pseudorhus.* It is situated between the cortex and phloem (see Plate I., Figs. 1 and 2). Sclerenchyma either connected with or isolated from the continuous ring is often developed in the cortex and in the outer part of the phloem. Radlkofer [11] remarks that the ring of sclerenchyma is characteristic of the bark of nearly all of the genera of Sapindaceæ. Sections of the bark of the stem when heated in distilled water for one hour and treated with the sulphuric acid-alcohol combination showed no reddish-violet colouration. On the other hand sections of the same tissues placed in absolute alcohol for one hour and treated with the reagent gave a positive colour reaction in the walls of many of the cells of the tissues which gave the positive reaction in the original sections which were not treated with absolute alcohol. It is therefore assumed that saponin is present in the walls of many of the sclerenchyma cells and in the walls of many of the bast fibres and parenchyma cells of the outer phloem.

Owing to the presence of a large amount of sclerenchyma in the bark of the stem, very thin sections of it could not be cut with ease. For this reason observations on the distribution of saponin in the bark of the stem were not so precise as those made upon sections of branchlets. No fresh wood of the stem was available for investigation.

Branchlets about 9 mm. in diameter were selected for study. Before commencing microscopical work it was ascertained that small pieces of the bark and wood, after being placed in distilled water, produced a foam on the surface of the liquid when it was shaken. The froth was more abundant in the solutions obtained from the bark. Sections of the branchlets upon treatment with the sulphuric acid-alcohol combination showed the reddish-violet colouration in the walls of many of the cells of the cortex, in the walls of some of the cells of the sclerenchyma, and in the walls of many of the bast fibres and parenchyma cells of the outer phloem. The cells of the periderm did not show the colour reaction. In some sections the most intense colour was developed in the immediate vicinity of large sclerenchyma cells. These sclerenchyma cells were surrounded by the reddish-violet colour and were situated on the inner side of the sclerenchyma ring. The wood of the branchlets gave faint reactions which were confined to the very young wood. The walls of some of the wood rays, of some of the wood fibres, and of some of the vessels showed a faint reddish-violet colour.

Both the wood and bark of branchlets gave negative reactions after being heated in distilled water for one hour, and positive reactions after treatment with absolute alcohol. Sections which had remained in absolute alcohol for several days showed the colour reaction with the sulphuric acid-alcohol in the same tissues which gave positive results with fresh material. The sclerenchyma ring in the bark of the branchlet measuring 9 mm. in diameter was very irregular and its maximum breadth was ·48 mm. The structure of the outer part of the bark of the branchlets is shown in Figs. 1, 2, and 3, Plates I. and II.

IV.—The Location of Saponin in the Root.

The material for investigation was taken from a large tree, and consisted of a secondary root 5 mm. in diameter. Small pieces of the bark and wood produced abundant frothing on shaking the distilled water in which they were steeped. As in the stem, a ring or sheath of sclerenchyma occurs between the cortex and phloem. The application of the sulphuric acid-alcohol combination to sections showed that saponin in the secondary root is distributed in a similar manner to that in the branchlets. The cortex, outer part of the phloem, and the very young wood gave positive reactions, and the reddish-violet colour was principally located in the cell walls. As in the branchlets, saponin was not uniformly distributed but occurred in many of the cells of the tissues.

The young wood of the root reacted much more strongly than that of the branchlets, and an intense reddish-violet colour developed in two or three rows of the wood fibres nearest to the cambium. The bast fibres and parenchyma were the parts of the outer phloem most affected by the testing solution. The sections treated with absolute alcohol and those heated in distilled water gave positive and negative reactions respectively when subjected to the action of the sulphuric acid-alcohol combination. The periderm yielded no indication of the presence in it of saponin. The structure of the outer part of the secondary root is shown in Fig. 4, Plate II.

V.—The Location of Saponin in the Walls of the Fruit.

The fruit is three-lobed and three-celled. Externally it is covered by dense, brown, rigid hairs or setæ. The walls of the fruit are very thick and hard. They are bounded externally and internally by a coating of parenchymatous tissue in which groups of sclerenchyma are embedded. The part surrounded by the external and internal coatings is composed of loose-celled tissue. Numerous vascular bundles passing from the internal coating to the external one traverse the loose-celled tissue. The walls of immature fresh fruit were examined. Small pieces immersed in distilled water and shaken produced on the surface of the solution an abundant froth which was immediately dispersed by a few drops of alcohol. Transverse sections of the walls when treated with the sulphuric acid-alcohol combination showed the reddish-violet colour in the walls of many of the cells of the sclerenchyma groups and in many of the spiral vessels of the vascular bundles. Some of the cells in each instance remained uncoloured.

The sections treated with absolute alcohol for one hour and subjected to the sulphuric acid-alcohol combination gave results similar to those of the original sections which were not treated with absolute alcohol. The sections heated in water for one hour when placed in the testing reagent developed a very faint reddish-violet colour in some of the spiral vessels of the vascular bundles but the sclerenchyma cells remained unaffected. Evidently the saponin was not thoroughly extracted from some of the spiral vessels by the treatment with water. Unfortunately no seeds were available for examination. In the fruits collected the ovules remained rudimentary.

VI.—The Location of Saponin in the Leaflets.

The observations outlined in this section were made before the writer was aware of Hamlyn-Harris and Smith's statement [7] that they had found the leaves of the species to be free of saponin. Sections cut in a transverse direction to the midrib of the leaflet, when treated with the sulphuric acid-alcohol combination, developed the reddish-violet colour in the cells of the xylem of the vascular bundles composing the internal part of the midrib, in a few of the cells composing the sheath of sclerenchyma surrounding the vascular bundles of the midrib, and in many of the cells surrounding the sclerenchyma sheath. The colour reaction was also observed in the spiral vessels of some of the vascular bundles composing the smaller veins of the leaflets. Although some of the colour was present in the interior of the cells, the greater part was concentrated in the cell walls. The remaining tissues of the leaflet gave negative results with the reagent.

Sections placed in absolute alcohol for one hour reacted in the same way as the original ones. Some sections which were stored in absolute alcohol for two days also showed the colour reaction in a similar manner when treated with the sulphuric acid-alcohol combination. The sections heated in water for one hour, however, retained some of their property to produce with the reagent the reddish-violet colour, which in this instance was decidedly fainter than that of untreated sections. It is therefore evident that the substance producing the reddish-violet colour with the reagent is only partly extracted by heating in water for one hour. The midribs of six leaflets were dissected out, cut into small pieces, and placed in distilled water for one hour. The solution when shaken produced a small amount of froth which was dispersed by the addition of a few drops of alcohol.

VII.—The Location of Saponin in the Young Twigs.

In order to test the validity of some ideas which were suggested by the distribution of saponin in other parts of the plant, it was decided to ascertain its location in the very young twigs. For this purpose young twigs were sectioned at positions from 6 to 9 mm. below the growing point. Sections when placed in distilled water for 30 minutes produced a froth which was immediately dispersed by a few drops of alcohol. Sections treated with the sulphuric acid-alcohol combination developed the reddish-violet colouration in a few of the cells of the cortex, in the cells composing the sclerenchyma groups situated in the cortex near the projecting angles of the twig, in all of the cells composing the sclerenchyma ring, in all of the cells composing the xylem groups, and in many of the lignified cells of the medulla. It was observed that the colour was less in evidence in the cells of the cortex of these sections than in those of the branchlets. The reddish-violet colour was mostly concentrated in the cell walls, but it was also present in the small lumina of many of the sclerenchyma cells.

The sections treated with absolute alcohol for one hour and then placed in the reagent gave results similar to those obtained by placing sections direct in the reagent. The sections heated in distilled water for one hour and then placed in the reagent showed a faint reddish-violet colour in a few of the cells of some of the xylem groups; otherwise the tissues gave negative results. The xylem groups in which the faint reddish-violet colour was formed after heating the sections in water constituted a very small proportion of the number which gave positive results in the sections placed directly in the sulphuric acid-alcohol combination.

The sclerenchyma ring in the bark of the young twigs which were sectioned was much more regular than that of the branchlets. It measured ·04 to ·06 mm. in breadth.

VIII.—Interpretation of Results.

The results obtained from the sections of the leaflets were not so definite as those produced by the other parts examined. The saponin-like substance in the midrib of the leaflets is evidently less soluble in water than the saponin demonstrated in other parts of the tree. According to Kobert [8, p. 244] a few saponins are only soluble in water to which a few drops of alkali have been added. The saponin-like substance in the midrib of the leaflets may not be entirely different from saponin in the other parts, as its location corresponds with that of saponin in some of the other tissues. For instance, it occurs in tissue adjacent to a sclerenchyma sheath and is sometimes located in the cells of the sclerenchyma sheath. In this respect its location is comparable to that of saponin in the cortex and sclerenchyma sheath of the branchlets and in the cortex of the roots. It also occurs in the cell walls of the xylem of the vascular bundles of the midrib, and is in this instance similar in location to saponin in the xylem groups of the young twigs and in the xylem of the roots. The absence of saponin from almost the whole of the chlorophyllous tissue of the leaflets was indicated by the investigations. This observation is partly confirmed by Hamlyn-Harris and Smith [7], who found the leaves to be free of saponin. It suggests that saponin in this species is not a direct product of photosynthesis.

In some of the tissues saponin was not uniformly distributed. It was found to occur irregularly in the cortex and outer phloem of the branchlets and roots. In the xylem groups and sclerenchyma sheath of the young twigs it was evenly distributed. The saponin (?) in the xylem of the vascular bundles of the midrib of the leaflets was also generally and evenly distributed. In all of the tissues examined the greatest concentration of saponin was found in the cell walls.

The possible connection of saponin with the formation of the cell walls of the sclerenchyma and xylem was suggested to the writer by the position of saponin in the sections of the stem, branchlets, roots, and walls of the fruit. Saponin was often concentrated in the cell walls of sclerenchyma. Examples were provided in the case of the sections of the walls of the fruit and of the bark of the stem and branchlets. In the root the walls of the very young wood fibres showed an intense reaction for saponin, and the presence of a slight amount of saponin was indicated in the walls of the cells of the very young wood of the branchlets. To test the validity of the hypothesis associating saponin with cell-wall formation, it was decided to ascertain the location of saponin in the very young twigs. If saponin is connected with the construction of the walls of the cells of the sclerenchyma and xylem, it could be anticipated that saponin would be concentrated in the walls of these kinds of tissue in the young twigs, because sclerenchyma and xylem are being formed or are only recently formed in this part of the plant. The result of the investigation of the young twigs supported the hypothesis in a positive way. The entire sclerenchyma sheath, the sclerenchyma groups in the cortex near the angles of the twigs, and all of the cells of the xylem groups showed an intense reaction for saponin, and the colour reaction was most strongly developed in the cell walls.

The presence of saponin in the bast fibres and parenchyma of the outer part of the phloem of the branchlets could be explained by the fact that these tissue elements are the ones which are transformed into sclerenchyma as growth proceeds. In the cortex of the branchlets saponin is also abundant in many of the cells. Although it would be difficult to show that the actual cortical cells which contain saponin are in course of conversion into sclerenchyma, there exists in the cortex of the branchlets a large amount of sclerenchyma either in groups or in the form of isolated cells.

A very large amount of sclerenchyma is formed in the outer portion of the bark of the branchlets. This is shown by the fact that the sclerenchyma sheath in the young twigs measured only ·04 to ·06 mm. in thickness while in the branchlets measuring 9 mm. in diameter the sheath of sclerenchyma attained a maximum breadth of ·48 mm. The photomicrograph of the transverse section of the branchlet which is reproduced in Fig. 1 shows the great extent of the sclerenchyma and the irregular thickness of the sheath which it forms.

IX.—The Function of Saponin in the Species.

The fact that saponin was found in greatest concentration in the cell walls suggests that its function is concerned with the construction or composition of the cell walls. The presence of saponin in, or its association particularly with, the cell walls of sclerenchyma and xylem (wood) appears to connect it with the development of these kinds of tissue. The association of saponin with the structure or composition of cell walls, which are composed of either cellulose or wood, is partly supported by the facts that saponins contain carbohydrates and that cellulose is a complex carbohydrate which also enters in large proportions into the composition of wood. The investigations have not shown where saponin originates in the species. It is evidently absent from almost the whole of the chlorophyllous tissue of the leaflets. Possibly it arises in the protoplasm and is transferred in very dilute solution from cell to cell through the perforations of the cell walls.

X.—Summary.

Saponin was found to be located in the following parts of the tree:—Many of the cells of the cortex of the stem, branchlets, and secondary roots; some of the cells of the sclerenchyma sheath of the stem, branchlets, and secondary roots; all of the cells of the sclerenchyma sheath of the young twigs; many of the bast fibres and parenchyma cells of the outer part of the phloem of the stem, branchlets, and secondary roots; all of the cells of the xylem groups of the young twigs; the very young wood fibres of the secondary root; many of the cells of the sclerenchyma groups in the walls of the fruit; and many

of the spiral vessels of the vascular bundles in the walls of the fruit. Faint reactions for saponin were shown by the various tissue elements of the very young wood of the branchlets. The greatest concentration of saponin was found in the cell walls of the various tissues. Almost the whole of the chlorophyllous tissue of the leaflets gave negative reactions with the testing reagent (concentrated sulphuric acid and absolute alcohol in equal parts by volume). A saponin-like substance was located in the cell walls of the xylem of the vascular bundles in the midrib of the leaflets, and in the cells surrounding the sclerenchyma sheath of the midrib of the leaflets. This saponin-like substance was sometimes present also in the cells of the sclerenchyma sheath of the midrib. It differed from saponin found in the other parts in being less soluble in water.

The concentration of saponin in the cell walls suggests that it is concerned with the construction or composition of the cell walls. The frequent occurrence of saponin in association with sclerenchyma and xylem suggests that it may be especially connected with the elaboration of lignified and hardened tissue.

ACKNOWLEDGMENTS.

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REFERENCES.

1. Bailey, F. M.—The Flora of Queensland, 1, 293, 1899.
2. Bentham, G.—Flora Australiensis, 1, 459, 1863.
3. British Pharmaceutical Codex, 980, 1923.
4. Czapek, F.—Biochemie der Pflanzen, 3rd Auflage, 3, 525, 1925.
5. Greshoff, M.—Phytochemical Investigations at Kew. Kew Bulletin 397, 1909.
6. Haas, P., and T. G. Hill.—An Introduction to the Chemistry of Plant Products, 3rd edn., 1, 181, 1921.
7. Hamlyn-Harris, R., and Frank Smith.—On Fish Poisoning and Poisons employed among the Aborigines of Queensland. Memoirs of the Queensland Museum, v., 9, 1916.
8. Kobert, R.—Saponins: their Properties, Composition, and Uses. Translated by W. J. Dilling. Pharmaceutical Journal, 86, 244, Feb. 1911, 293, March 1911.
9. Maiden, J. H.—Forest Flora of New South Wales, vi., 55, 1917.
10. Molisch, H.—Mikrochemie der Pflanze, 2nd Auflage, 195, 1921.
11. Radlkofer, L.—Die naturlichen Pflanzenfamilien, III. Teil. 5 Abt. 281, 1896.
12. Swain, E. H. F.—Annual Report of the Director of Forests for the Year 1918 (Dept. Public Lands, Queensland), p. 8, 1919.

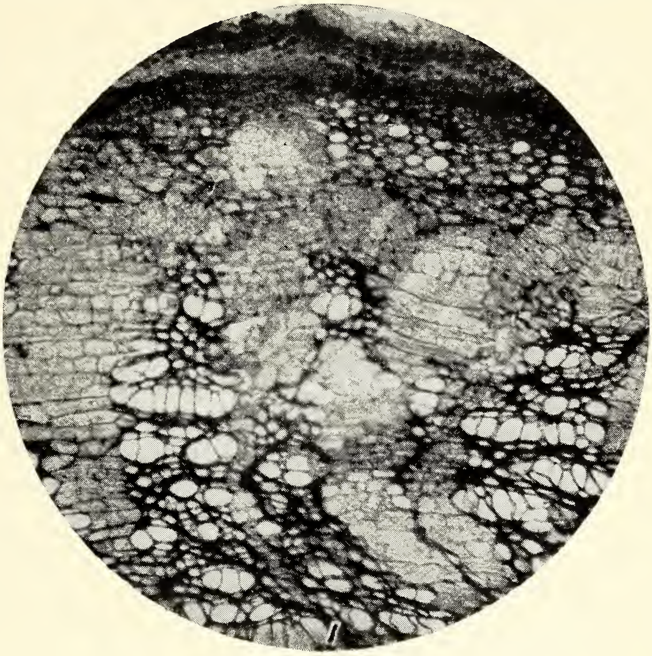
EXPLANATION OF PLATES I., II.

The photomicrographs illustrate the structure of some of the tissues examined. Figs. 1 and 4 were photographed with a 16 mm. apochromat N.A. 0.3 and compensating ocular 8. Figs. 2 and 3 were photographed with a 4 mm. apochromat N.A. 0.95 and compensating ocular 4.

Plate I.

1. Transverse section of outer part of bark of branchlet 9 mm. in diameter. The outer surface is shown in the uppermost part of the picture. Inwards from the surface the dark band of small cells traversed from left to right by a lighter portion is the periderm. Inwards from the periderm is the comparatively large-celled cortex. In the cortex slightly towards the left is a group of sclerenchyma. Inwards from the cortex is the sclerenchyma ring which is composed of irregular groups of cells with ill-defined or small lumina (cavities). The sclerenchyma with very small cells in the upper part of the sheath consists of thickened bast fibres in section. The sclerenchyma extends in irregular masses towards the lowermost part of the picture and is shown as pale in the photograph. The comparatively large, clear apertures in the lower half represent the sieve-tubes in section. The dark, thick-walled cells between the sieve-tubes are bast fibres. × 100.

2. Radial section through outermost part of bark of branchlet 9 mm. in diameter. On extreme right the surface of the bark is shown. Inwards from it is the periderm consisting of two series of small cells arranged in horizontal rows. Inwards from the periderm is the cortex consisting of large cells. The cortex is bounded on the left by the perpendicular band constituting the sclerenchyma ring, which is composed of highly lignified bast fibres and, on the upper left side, of stone cells. Some unlignified parenchyma is shown on the lower left side of the sclerenchyma ring. × 170.



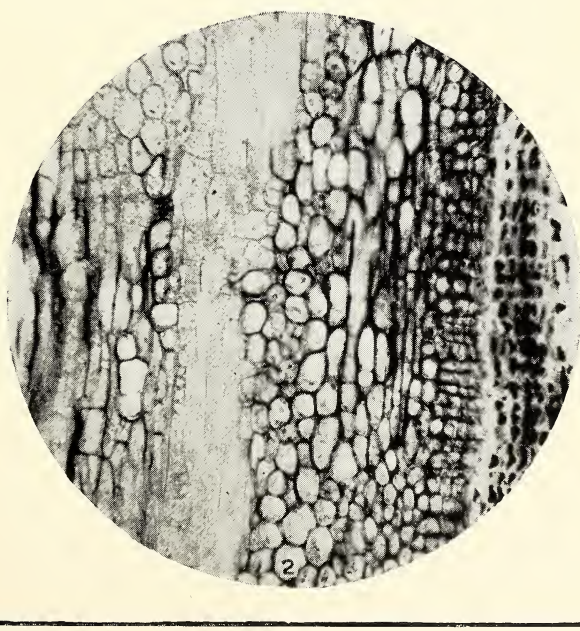


Fig. 1.—Transverse section of outer part of bark of branchlet of *Jagera pseudorhus*. × 100. Fig. 2.—Radial section of outer part of bark of branchlet of *Jagera pseudorhus*. × 170.

PLATE II.

3. Part of the same section the outermost portion of which is shown in Fig. 2. The outer part of the phloem is shown in this picture. The large, open, vessel-like elements passing from top to bottom of picture are sieve-tubes. The sieve-fields on the lateral walls of the sieve-tubes are indistinctly seen in places. Some bast fibres are shown between the sieve-tubes on the right half of the picture. They are traversed in places by septa and accompanied by parenchyma which is shown towards the top and bottom. On the extreme left elongated parenchyma is shown. × 170.

4. Transverse section of secondary root 5 mm. in diameter showing outer portion. the broad, dark band in the upper part indicates the position of the periderm. Below it the cortex, consisting principally of very large cells, is shown. Below the cortex the irregular band of tissue composed of cells with ill-defined boundaries is the sclerenchyma ring. In the middle of the picture the sclerenchyma ring is seen projecting inwards and flanking two large sieve-tubes. Below the sclerenchyma ring the dark-celled tissue is the phloem in which the large apertures represent sieve-tubes in section. The lowermost portion of the picture shows the wood. × 100.

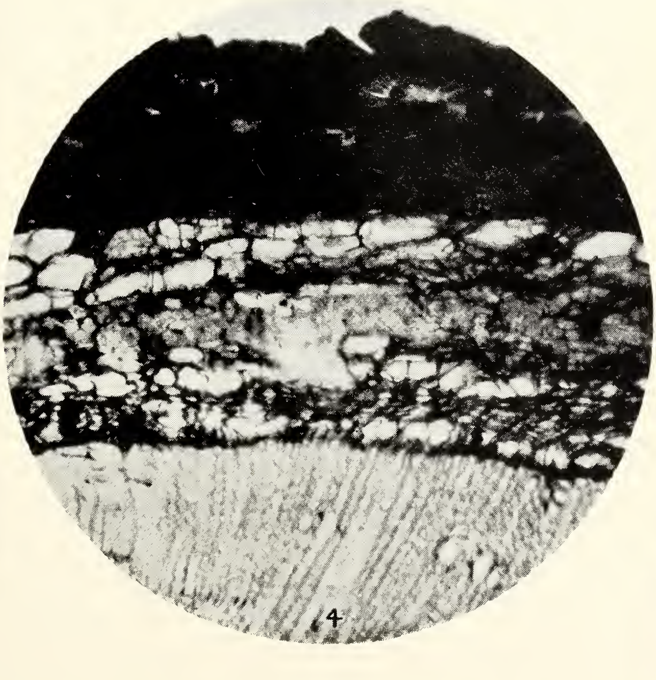


Fig. 3.—Radial section of outer part of phloem of branchlet of *Jagera pseudorhus*. × 170. Fig. 4.—Transverse section of outer part of root of *Jagera pseudorhus*. × 100.

Revisional Notes on Described Australian Robber Flies of the Genus *Ommatius* (Asilidae).

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(Placed before the Royal Society of Queensland, 25th June, 1928.)

(Eight Text-figures.)

THE illustrations of the genitalia given here are restricted to the lateral view of the upper and lower forceps and, when showing, the ventral plate. The lamellæ are sometimes hidden when viewed from this aspect, but invariably they are situated just below the dorsal process of the upper forceps when that structure is present, and it may be so found on the last four species described below. Care must be taken not to confuse the lamellæ with the outline of the parts illustrated when comparisons are being made. The shape of the genitalia, as exhibited by the eight species here given, exceeds in variety that of any other Australian genus I am acquainted with; there are up to five distinctive types, which suggests that the genus is a complex one, but the female ovipositor of all the species appears to conform to but one type that is not dissimilar to that of *Neoaratus.*

It would seem that White confused species to a certain extent, and so, when his material is re-examined, it may be possible to modify the synonymic references given here. The adjustments seem to be necessary under *O. dimidiatus* and *O. lema,* for the former is a very consistent form that White seems to have regarded as a variety of the latter, which itself is a species that varies in colour. Again, a variation of *O. lema* was described by him as a distinct species. The synonymy regarding the other species seems to be clear enough, except perhaps that of *O. vitticrus,* which, as known to me, may ultimately prove to be a complex of two very closely related species.

In the Gibbons collection, now in the Australian Museum, Sydney, there are four named species of *Ommatius* : *O. distinctus* Ricardo, a paratype, *O. angustiventris,* and two others under manuscript names, one being a specimen of *O. dimidiatus* Macq., the other I did not identify at time examined, but is I think *O. lema* Walker; it bears the number 8 on the pin.

Key to the species of the genus Ommatius.

1. Genitalia of the male with the upper forceps simple .. .. 2.
   Genitalia with one or more processes on the upper forceps .. .. .. 4.
2. Upper forceps short and simple, the lower forceps much longer and with a process on lower edge .. .. *chinensis* Ricardo.
   Upper forceps much longer than the lower ones, lower forceps simple .. .. 3.
3. Femora entirely black .. .. *angustiventris* Macq.
   Femora only partly black .. .. *vitticrus* Big.
4. Upper forceps produced into a slender process that is broadened out, spatulate form, at the apex .. .. *dimidiatus* Macq.
   Upper forceps with from one to three processes .. .. 5.
5. Upper forceps with one or two processes .. .. 6.
   Upper forceps with three processes .. .. 7.
6. Moustache entirely white. One process issuing from the upper corner of the forceps .. .. *queenslandi* Ric.
   Moustache with at least some black hairs. The longer of two processes issues from the lower corner of forceps .. .. .. *pilosus* White.
7. Upper process of upper forceps very slender and somewhat lamella-like. Intermediate process projecting well beyond the others. Lowest process somewhat spatulate .. .. *lema* Walker.
   All three processes subequal in length .. .. .. *distinctus* Ricardo.

OMMATIUS CHINENSIS Fab. (?). (Fig. 1.)

Ricardo 1913, p. 163.

Ommatius chinensis Fab. is an extra-limital form, and its identity with the one referred to by Miss Ricardo is not certain. Ricardo recorded it from Queensland, but she gave a very generalised description, and subsequently in Australian collections the name was wrongly attributed to *O. vitticrus* Bigot. There are two specimens before me that would appear to be that species described by Ricardo under the name, one a female captured in Brisbane (November 1922), the other a male bred by G. Bates, Bundaberg (14-11-27), and sent for identification by Mr. R. W. Mungomery, who subsequently donated it to the Queensland Museum.

The genitalia of the male on this species is so extraordinarily complicated that I have had difficulty in reducing its components to simple terms. The upper forceps are two simple plates, rather well defined, but overlying the larger and more laterally placed lower forceps. Ventrally, from near the base of these lower forceps, there arises a slender process that ends in a hook-shaped apex, and that is seen to cover what can only be regarded as the lower edge of the modified clasper. The ventral plate is represented by a pair of horizontal and contiguous processes, slender, hairy, and somewhat palp-like.

OMMATIUS ANGUSTIVENTRIS Macquart. (Fig. 2.)

Macquart 1849, p. 89; Schiner 1867, p. 410; Ricardo 1913, p. 163.
O. coroebus Walker 1849, p. 472; and 1855, p. 759.

The synonymy was given by Ricardo. This common form is in nearly every collection, correctly identified. It is a black species with tibiæ and markings on the thorax bright yellow. New South Wales is the only State in which it is known to occur.

OMMATIUS VITTICRUS Bigot. (Fig. 3.)

Bigot 1876, p. lxxxv.; Ricardo 1913, p. 164. *O. mackayi* Ricardo 1913, p. 165.

I think the above synonymy will prove correct. This form seems to be the common one of Southern Queensland, to which area it may be confined. Though quite distinctive in general colouration and appearance, very old specimens may be confused with *angustiventris*, but the leg colouration will distinguish it. All the legs have a black stripe on the otherwise yellow femora, or the hind femora may be black only at the apex. The specimen with the latter colour also has the abdomen entirely yellowish and the moustache entirely white, but it does not exhibit any marked difference in genitalia.

OMMATIUS DIMIDIATUS Macquart. (Fig. 4.)

Macquart 1849, p. 90; Ricardo 1913, p. 164; White 1916, p. 168.

It appears that this species occurs throughout the settled coastal area of Queensland, and extends into New South Wales at least as far as Sydney. White's reference appears to be a complex, for he refers to a form on which the black is "on the posterior pair sometimes reduced to an elongate spot"; this character of the femora is consistent in my long series, so it is possible that White had a small *O. lema* amongst his series of four specimens. Macquart described it from Tasmania in the fourth supplement, but the locality is erroneous. Ricardo referred to it from North Queensland as "probably nearly allied" to *dimidiatus*, but there can be little doubt concerning its identity.

OMMATIUS QUEENSLANDI Ricardo. (Fig. 5.)

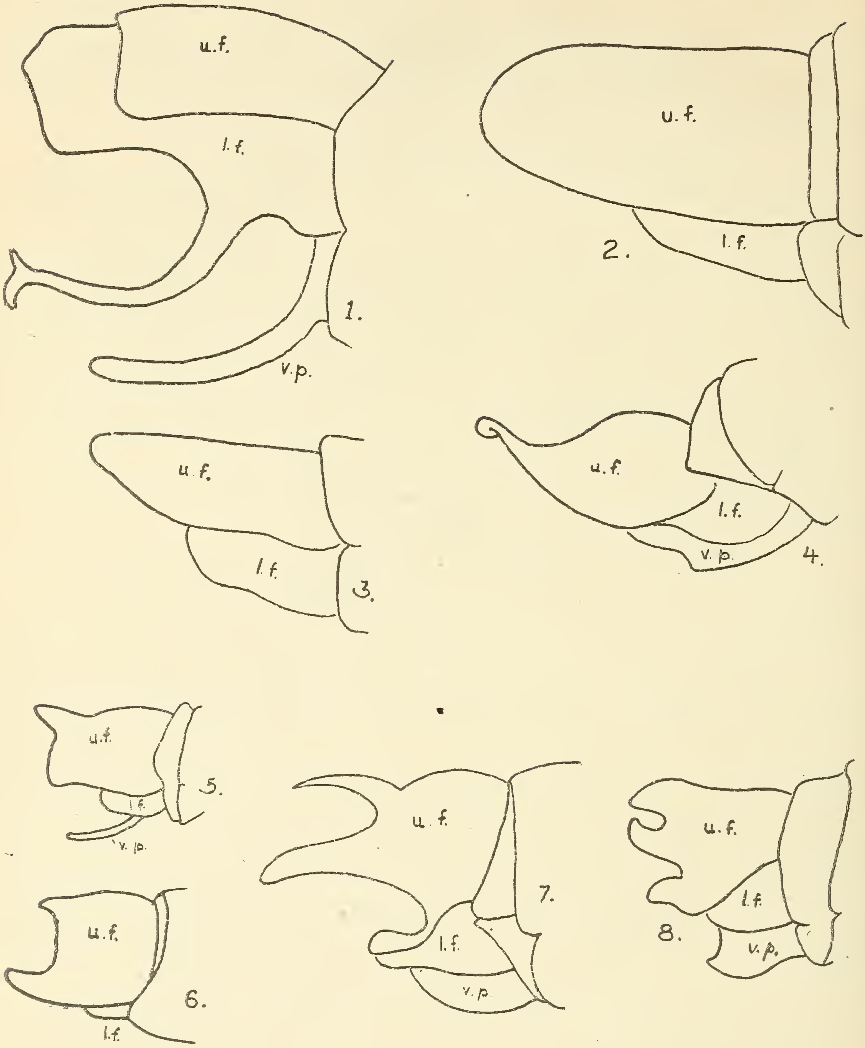
Ricardo 1913, p. 166.

A small black form that may be readily confused with one or other of the smaller species. Besides in the male genitalic characters, it may be recognised by the entirely white moustache of both sexes. The process on the upper forceps is somewhat small, and situated on the upper corner of the apical border; the apical edge of these forceps is bent inwards and has one, if not two, dentations along that edge, but these cannot be regarded as processes. There is only one pair before me (27th and 25th December, 1920), both from Brisbane.

OMMATIUS PILOSUS White. (Fig. 6.)

White 1916, p. 169; Hardy 1920, p. 186. *O. levis* White 1916, p. 170.

This synonymy was previously recorded by me. I have a sketch of the genitalia taken from the type of *O. pilosus*, and this conforms to



EXPLANATION OF FIGURES.

Male genitalia of—

Fig. 1.—*Ommatius chinensis* Ricardo.
Fig. 2.—*Ommatius angustiventris* Macquart.
Fig. 3.—*Ommatius vitticrus* Bigot.
Fig. 4.—*Ommatius dimidiatus* Macquart.
Fig. 5.—*Ommatius queenslandi* Ricardo.
Fig. 6.—*Ommatius pilosus* White.
Fig. 7.—*Ommatius lema* Walker.
Fig. 8.—*Ommatius distinctus* Ricardo.

l.f., Lower forceps; *u.f.*, upper forceps; *v.p.*, ventral plate.

that given here; the genitalia of specimens conforming to the description of the typical *O. levis* are identical. The species is as yet known only from Tasmania, but White added South Australia to its range, probably erroneously.

OMMATIUS LEMA Walker. (Fig. 7.)

Walker 1849, p. 472; and 1855, p. 759; Ricardo 1913, p. 164. *O. obscurus* White 1917, p. 89.

This synonymy is tentatively suggested, as I have not seen a specimen that fits White's description in every respect. The femora may be entirely black (*obscurus*) or the underside may be brown or red (*lema*); White may have included the latter as his *dimidiatus*. The red colour, when present, on the otherwise black femora is perhaps the one character that most readily distinguished the female from other species. Also the outer side of the tibiæ is much lighter than the other parts of this segment, which again aids in the determination of the female, but the character is not confined to the species. In describing *O. obscurus*, White referred to the tibiæ as being "brown at the knees"; I have not seen this restriction, but he also states that the costal margin is tinged with brown, especially at the tip, which wing character applies only to the present form.

All my specimens are from Brisbane, where it occurs somewhat abundantly from October to January resting on twigs; previously it was only known from New South Wales. This species can scarcely be the *dimidiatus* of Macquart, despite the fact Macquart states "legs red, femora above and tibiæ below black" (Ricardo's translation), for he gives the dimensions as only 4 lines (about 8 mm.), and states "Ailes claires."

OMMATIUS DISTINCTUS Ricardo. (Fig. 8.)

Ricardo 1918, p. 66.

This species, hitherto only known from Queensland, is also represented from Darwin, Northern Territory, by one male. The form is readily recognised by the fuscous spot situated at the apex of the wing, but on the female the spot tends to disappear.

LIST OF WORKS REFERRED TO.

Macquart, 1849.—Dipteres Exotique nouveaux ou peu connus. Supplement 4.

Walker, 1849 and 1855.—List of Dipterous Insects in the British Museum, ii.; and vii. suppl. 3.

Schiner, 1867.—Kaiserlich-Koenigliche Zoologisch-Botanische Gesellschaft. Verhandlungen, xvii.

Bigot, 1876.—Societe Entomologique de France (5), Bull. lxxxv.

Ricardo, 1913 and 1918.—Annals and Magazine of Natural History (8) xi.; and (9) i.

White, 1916 and 1917.—Proceedings of the Royal Society of Tasmania for these years.

Hardy, 1920.—Proceedings of the Linnean Society of New South Wales, xlv.

A Geological Reconnaissance of Part of the Aitape District, Mandated Territory of New Guinea.

By H. G. RAGGATT, B.Sc., Geological Survey of New South Wales.

(One Geological Map and Section, Three Text-figures, Six Photographs.)

Plates III., IV., and V.

(*Communicated by Professor H. C. Richards, D.Sc., to the Royal Society of Queensland, 27th August, 1928.*)

INTRODUCTION.

VERY little geological work has been done in the Mandated Territory of New Guinea, but recently several exploratory parties have been engaged in the search for oil, and a little has been added to our general knowledge of this large region.

All such parties have encountered similar difficulties, many of which are common to geological work in any unexplored country, but some of which are peculiar to tropical regions in general and to New Guinea in particular. Chief of these are decreased efficiency due to trying climatic conditions, malaria, and the general difficulties of maintaining food supplies, communication, and transport.

In this paper are indicated, in a general way, the principal geographical and geological features of that part of the Aitape district of which the writer has personal knowledge, together with notes on adjoining areas. Six months were spent in continuous fieldwork in this district by a party employed by the Pacific Islands Investment Company of Sydney, consisting of Mr. W. A. Chadwick, L.S., Mr. H. A. Robinson, surveyor's assistant, Mr. R. A. Hanlin (in charge of food supply and transport), and the writer.

I am greatly indebted to the Pacific Islands Investment Company for permission to use information gained whilst in their employ. My thanks are due to Mr. Tom Iredale for identification of shells, and to Mr. W. S. Dun for remarks as to their general palæontological aspect.

I am much indebted for corrections and useful suggestions to Mr. E. C. Andrews, Professor H. C. Richards, Assistant Professor W. R. Browne, and Mr. G. D. Osborne.

PREVIOUS WORK.

Early coastal exploration of New Guinea belongs more to history than to geography or geology.[1]

Germany annexed the Territory in 1885, but until 1913 the exploratory work done was confined to the coast and the larger rivers such as the Sepik and Ramu.

The Stolle and Cumberlege expedition mapped a large part of the Sepik River and its tributaries during 1913 and 1914, and it is believed that the Germans intended to push on vigorously with inland exploration, particularly with reference to economic geology and botany; but of course the Great War put an end to these activities.

Since the Australian occupation, recruiters, traders, and patrol officers have been gradually pushing farther and farther afield.

In 1917 Captain Macintosh investigated oil occurrences in the Smein and Matapau areas, which lie about 40 and 45 miles, respectively, east of the limits of the accompanying map.

In 1919 Lieutenant Young made a patrol south from Vanimo (about 90 miles west from Aitape), crossed the main divide, and returned to Aitape.

During 1920-21 part of the Aitape district was examined by geologists of the Anglo-Persian Company. They confined their attention chiefly to Matapau and Ulau (*see* Map).

Government patrol officers have been over the coastal regions many times, and in 1925 an important patrol was carried out by Mr. A. Wilks into the region southward from Yakomul.

Mr. R. A. Hanlin had previously made a recruiting trip into the district inhabited by the Wa-pi tribes, southwards from Aitape, and in so doing was probably the first white man to visit many of the villages in this region.

The late Evan Stanley's report upon New Guinea makes general reference to the geology of the Aitape district, but no information is given on the map accompanying his report within the limits of the area examined by the writer. He also gives a summary[2] of the report of the Anglo-Persian Company's geologists on the Matapau area, and some general remarks upon the structure and disposition of Tertiary beds in the Aitape district.

In the Matapau district the geologists of the Anglo-Persian Company noted the following sequence in the Tertiary sediments:—

(*a*) *Upper Group*—2,400 ft. thick; foraminiferal mudstone, sandstone, and sandy mudstone intruded by diorite and granodiorite.

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[1] *See* Evan Stanley, "Salient Geological Features of the New Guinea Territory," 1922, pp. 7-11, 64-67. Aust. Ency., vol. ii., pp. 22-24.

[2] Evan Stanley, "Salient Geological Features of the New Guinea Territory," 1922, p. 66.

(*b*) *Middle Group*—2,300 ft. thick; massive conglomerate interbedded with blue micaceous sandstone and mudstone (unfossiliferous). Conglomerates cemented with calcareous material.

(*c*) *Lower Group*—200 ft. thick; blue micaceous sandstone, blue-grey mudstone, sandy mudstone, grit, and conglomerate.

FIELD WORK—METHODS.

Aitape, the administrative centre of the Aitape district, was naturally chosen as the base from which to carry out field investigations.

Having no reliable map upon which to base a survey, it became necessary to attempt a reconnaissance of the entire area.

The positions of the more important villages were fixed by Mr. Chadwick, using theodolite observations in conjunction with wireless time signals for the determination of longitude. Intermediate points were fixed by joint time traverses and occasional prismatic compass traverses—e.g., Kapoam villages.

In travelling from, say, A to B, where A is a fixed station, the position of B as given by the joint time traverses was plotted first. The position of B was then fixed, and the traverse corrected accordingly. There was never a very great error in the time traverses since each day's journey did not exceed about 10 miles, giving frequent accurate checks. Where possible the method of resection was employed also.

Aneroid readings (checked where possible by theodolite observations, e.g. at Mendam) were used for altitude determinations. Graphs of diurnal variation were found to be most regular, and over long periods readings taken at the same hour each day for the same station showed little variation. Graphs for widely separated points generally had the same form (*see* page 73).

In addition to the survey and geological work, the names of prominent natural features and villages were obtained from the natives. The names which appear on the map have been spelled according to the Continental vowel system (as in French), and have been placed on the map regardless of the current pronunciation used by white people on the New Guinea coast, except that Aitape has been allowed to remain, because it appears on many maps of New Guinea as such.

GEOGRAPHY.

(1) General Features.

Aitape, the administrative centre of the Aitape district, is situated on the north-east coast of the island of New Guinea, about 100 miles south-easterly from the eastern boundary of Dutch New Guinea.

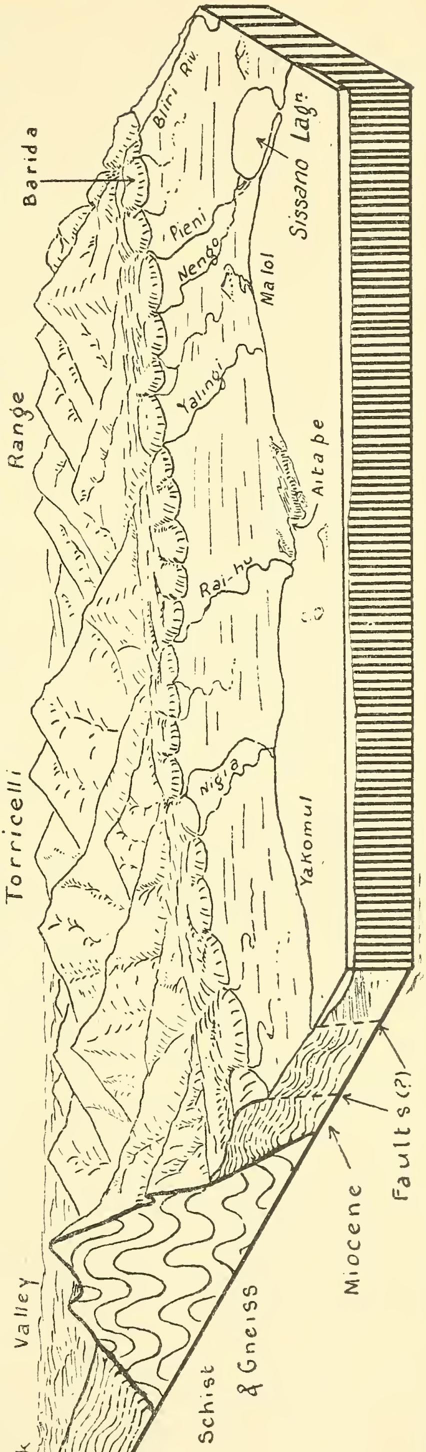
The area with which this report is chiefly concerned consists of approximately 1,000 square miles of country extending equally south-easterly and north-westerly from Aitape along a total coast-line of

70 miles, and inland about 30 miles from a coastal strip 22 miles wide, westerly from Aitape.

The whole of the area lies north of 3 deg. 30 min. south latitude. The general geographical features of the area are as follow:—

(i.) *Coastal Plain.*—The Coastal Plain is about 1 mile wide at Ulau; at Wom it is 4½ miles wide and it attains a maximum inland from Sissano, where its width is approximately 12 miles. It is for the most part low-lying and swampy, but includes some low hills near the coast. The hills are confined to the western half of the area —namely, St. Anna Mission, Aitape, Pultulul, Tepia. Considered as a percentage area of the coastal plain, however, these hills are insignificant.

The Coastal Plain is so little raised above sea-level that the large number of streams which flow through it inevitably meander as they approach the sea, in some places forming true deltas with numerous distributaries. The mouths of many of the larger rivers take the form of lagoons with a single entrance to the sea. In flood-time the crossing of these is very dangerous. The coast-line is practically straight. It trends about east-north-east, and has no large indentation throughout its entire length from the Sepik River to the Dutch border. With the exception of Vanimo, there are no deepwater bays of importance within the limits mentioned.



Block Diagram of Part of the Aitape District, showing the Principal Geographical Units— (1) Coastal Plain (Recent and Pleistocene Sediments), (2) Foothills (Miocene Beds), (3) Main Range (Schist and Gneiss), and (4) Inland Slopes (Miocene Beds).

(ii.) *Coastal Foothills.*—The Coastal Foothills are a well-defined area between the plain and the higher land of the Main Dividing Range. The foothills rise directly from the plain. By this is meant that a line joining the fronts of the hills is relatively straight and sub-parallel to the coast-line. This is well illustrated on the map where the native paths (from Nengien to Aiterap for example) follow pretty closely the line of junction between those two geographical units, forming an approximate contour line 150 ft. above sea-level.

The foothills have an average height of about 500 ft. and attain a maximum of approximately 1,000 ft. Here the streams are deeply entrenched and relatively swift-flowing (a rough estimate of the rate of flow of the Yalingi near Siauti suggests about 5 miles per hour). As the streams flow through the coastal plain they experience great loss in velocity, and their beds become filled with sandbanks and thickly strewn with snags in consequence. All the streams are liable to sudden floods (particularly at mid-afternoon), and during these periods it is inadvisable to attempt a crossing.

(iii.) *The Dividing Range.*—In this part of New Guinea the Dividing Range does not exceed 5,000 ft. in height. The highest point on the range south of Aitape appears to have been named by the natives "Subomoro." This point is close to the track by which the party returned from Wa-pi to Lupai, and on which the highest point reached was 4,600 ft. (aneroid).

Except in its higher portions, the main range is clothed in thick jungle. There is a distinct lessening in the thickness of the undergrowth above 3,000 ft.

The party crossed the range in two places and both tracks may be described as distinctly dangerous, although it would be a comparatively easy task to make a safe pedestrian road across the mountains, following either route. The rivers are deeply entrenched, and in many places stream dissection is so advanced that the way leads across narrow ridges no more than a few yards wide, from which the ground falls away steeply on either side to depths of 1,000 ft. or more.

(iv.) *The Inland Slopes.*—Southwards from about latitude 3 deg. 25 min. south, the hills are successively lower towards the Sepik Valley. Little is known of this portion of the area. In its more northern parts it is populated by the Wa-pi tribe, an industrious mountain people of good average physique.

The general features of the inland slopes are very similar to those of the coastal foothills.

(2) Topography and Drainage.

Some general idea of the topography has been given in the previous section. The coastal foothills and the inland slopes present many similar features, the outlook from Mendam and Epiop having many points in common.

From Epiop a good view can be obtained towards the main range of Papua, which on rare occasions may be distinguished with the unaided eye. The landscape consists of a number of separated parts from which the sharp angles of youth have been removed. There are few flat hilltops. These are replaced by sharp ridges along which native villages are forced to assume an elongated arrangement, and along which paths pursue a sinuous and hazardous course. It is a typical maturely dissected upland. (Plate V., fig. 2.)

These remarks apply with almost equal force to the whole area, except, of course, the coastal plain. Only near their sources do the streams exhibit any of the characteristics of youth.

The mature topography of the main divide is responsible for a peculiar anomaly—namely, water shortage in a region of high rainfall. The run-off is immediate and complete.

The shape of the few hills in the neighbourhood of Aitape has been determined by the inland (southerly) dip of the rocks and their differential hardnesses. These hills have well-defined slopes to the south, with scarps on the seaward side.

The coastal foothills have a general tendency to the same kind of feature in their more northerly parts, and dip-slopes are also particularly well developed in the inland slopes near Epiop. Here the bedding of the Tertiary sediments is exposed by land-slips, and may be seen to be approximately parallel to the surface slopes.

The stream pattern is interesting. The northward-flowing streams which drain into the sea are characterised by the absence of large tributaries. They all meander as they approach the sea, and some have true deltas. In plan they resemble trees devoid of branches for a considerable distance above the ground.

In a number of places tributaries enter the parent stream abnormally, so that there may be seen the phenomenon of two currents flowing in opposite directions in the one stream until the weaker is forced to turn and flow back with the stronger. A complete reversal of drainage during Recent time is suggested.

The Bliri River is by far the largest stream between Smein and the Dutch border. It rises on the southern slopes of the main divide, flows north-westward, then turns northward and becomes part of the coastal stream series. The Bliri (called Raimbrum at its mouth) must have been sufficiently well established to enable it to hold its course while the main range was being elevated.

Stream action since Tertiary time has been considerable. The few preserved sections of Post-Tertiary muds and gravels indicate a large amount of sedimentation. These beds have later been dissected and a vast amount of material must have been swept into the sea. Gravel-strewn beaches mark the presence of stream mouths, in some places, for as much as a mile distant from the present points of entry of the rivers into the sea.

Denudation of the land is still proceeding at a very rapid rate, but, over that part of the area where there is a fairly extensive plain bordering the coast, nothing but the finest silt reaches the ocean. In crossing the streams at their headwaters, one can feel a large number of pebbles being carried with the stream. Photographs of several of the coastal rivers show the extensive gravel-beds which are being built up by the coastal streams throughout the foothills. (Plate V., fig. 1.)

(3) Climate.

The area, as already stated, lies north of 3 deg. 30 min. south latitude, and the climate is therefore tropical.

In one word, the outstanding feature of the climate may be described as monotonous. Compared with temperatures to which Australians are accustomed, the mean temperature is low, but the humidity is much higher. The monotony of the climate is not so marked in the mountains, which also seem to be free from malaria. A trip to the mountains is distinctly invigorating to persons living on the coast. Periodic visits to a higher region would undoubtedly make life less irksome for those living in the coast districts. The late Evan Stanley has also stressed this point more than once.

The temperature and humidity figures are not available for Aitape district, those of Madang, the next adjoining district easterly from Aitape, being given instead, as likely to be very similar.[3]

Month.	Dry Bulb, 9 a.m.	Wet Bulb, 9 a.m.	Humidity per cent.	Mean Maximum Temperature	Mean Minimum Temperature	Mean Temperature	Highest Temperature	Lowest Temperature
January	81·8	77·0	80	88·0	74·3	81·2	91·8	68·0
February	81·2	76·6	80	87·5	74·1	80·8	92·0	71·0
March	81·3	76·8	80	86·7	74·0	80·4	92·0	71·0
April	81·4	77·4	83	87·3	74·0	80·6	92·0	70·0
May	81·6	77·3	82	87·4	74·2	80·8	92·0	71·5
June	81·5	77·0	81	86·9	73·7	80·3	91·5	69·0
July	81·3	76·9	81	86·7	74·3	80·5	92·2	70·0
August	81·9	76·7	77	86·9	73·9	80·4	91·0	70·0
September ..	82·3	77·2	79	87·7	74·2	81·0	92·5	70·3
October	82·7	77·4	78	87·2	74·1	80·6	92·0	70·0
November ..	82·4	77·4	79	87·7	74·2	81·0	91·7	70·5
December.. ..	82·2	77·2	79	87·7	74·3	81·0	92·0	68·5
For the Year ..	81·8	77·1	80	87·3	74·1	80·7	92·5	68·0

These figures are for the seven-year period ending 1924. It will be noted how little the humidity percentage varies from month to month from the yearly average, the average being 80 per cent., the minimum 77 per cent., and maximum 83 per cent.

[3] Dept. of Agriculture, Man. Terr. New Guinea, Leaflet No. 42.

The monotony of the climate is further emphasised by a study of the temperature figures. The minimum and maximum temperatures for each month are practically the same, and the difference between the maximum and the minimum over the whole period is only 24·5 per cent.

According to the official figures,[4] Aitape has the lowest rainfall for all districts in the New Guinea territory, but the figures are somewhat misleading if they are taken as being representative of the whole district. It should be noted that Aitape is situated on the coast some distance from the mountains. As the high land is approached the rainfall progressively increases. For instance, in the wet season, a village such as Waningi experiences heavy rain practically every afternoon between 2 p.m. and 4 p.m., and a tropical thunderstorm may be heard raging over Lupai and Waningi, whilst at Wom, at the foot of the hills, only very slight showers may be falling. In this connection compare the rainfall of Rabaul (average 86·19 in.) with Talasea (average 169·85 in.) and Gasmata (average 169·85 in.).

During 1923 the rainfall at Aitape amounted to 96·70 in., the average for three years being 85·85. (The average annual rainfall of Byron Bay, N.S.W., is 77·41 in.)

In the Aitape district the dry season, extending from July to November, is characterised by mild south-east winds; north-west winds commence towards the end of November and continue throughout the wet season until June or July. In the wet season it is advisable to try to reach the village selected as the objective for the day, in advance of the usual afternoon storm. This, as a rule, does not last very long (something like half an hour) and work may then be resumed in the vicinity of the village.

Previous remarks concerning the aneroid barometer and the general incidence of the afternoon storm are illustrated by the following figures:—

Aiterap (500 ft. A.S.L.).		Mendam (1,550 ft. A.S.L.).	
Time.	Aneroid reading in feet.	Time.	Aneroid reading in feet.
A.M.		A.M.	
10 30	1,460	8 0	2,375
11 30	1,500	9 0	2,390
P.M.	..	10 0	2,400
12 30	1,525	11 15	2,350
1 30	1,550	Noon.	2,350
2 30	1,575	P.M.	
3 30	1,610	1 0	2,400
4 30	Storm	2 0	2,425
4 45	1,575	2 15 } 2 30 }	Storm
5 30	1,560	3 0	2,390
6 30	1,550	4 0	2,380
8 30	1,450	5 0	2,360
9 15	1,450	6 0	2,360

[4] Dept. of Agriculture, Man. Terr. New Guinea, Leaflet No. 44.

(4) Vegetation.

So far as vegetation is concerned, there are two sharply contrasted types of country in New Guinea, namely forest and grass lands. The whole of the area actually travelled over during this investigation consists of forest. ''Kunai'' or grass lands are common around Rabaul and eastwards from Aitape, notably about Monumbo (Potsdamhafen). Inland from this locality there are large areas of ''Kunai,'' this grass constituting practically the sole building material used by the natives.

Looking down towards the Sepik River from Epiop there are vast areas to be seen which probably consist of ''Kunai'' or some similar kind of grass.

The forest or jungle growth appears to be very similar from sea-level to about 3,000 ft. Above that level there is marked thinning in the undergrowth. Here the ground is carpeted with beautiful ferns and begonia-like plants which must be trampled upon at every step. The trunks of the trees are covered with mosses and lichens. Palms are rare, and appear to be all of the type known to the natives as ''limbong.'' This palm is used in many ways. The trunk is split into sections and used for floors and sides of houses. The leaves are used as thatch, and in time of emergency the succulent parts may be used as food.

In the jungle it is impossible to diverge from cut paths. The trees grow thickly together, the ground is obscured by dense undergrowth, and vines grow thickly over all. Calamus and D'Albertis abound. The trees are decorated by staghorns and graceful orchids, and the ground is littered with decayed and rotting vegetation and brightly coloured native fruits. Swamp areas are invariably occupied by the sago-palm (sac-sac).

There is abundant softwood timber available for the erection of temporary dwellings and shelters, but hardwood trees such as Quila and Afzelia are not plentiful, except in certain sections.

(5) Settlement, Communication, and Transport.

White settlement is confined to the coast, and practically all the transport of goods from station to station is done by schooner.

Extensive native settlement exists on the beach and to a lesser extent on the seaward side of the coastal foothills, but over practically the whole of the coastal plain there are few native villages. The main divide is almost uninhabited. On the inland slopes again there is a large native population. Much might be said upon the very definite control which the geography of the region has exercised upon the distribution of population.

There is a coastal ''road'' (such being the ''pidgin'' term universally used for any kind of track) which traverses the whole of the seaboard. The ''road'' is a path from one to two yards wide, which is kept cleared by natives for certain allotted distances each side of the various villages. About Aitape itself where there is no native village the work is done by prisoners.

It is possible to travel over the coastal track on horseback, but there are many river crossings which necessitate frequent delays. Over certain sections of the coast bicycles may be used, but this means of travel is only practicable during the south-east season, when wave action is at a minimum and the beach sand has had time to consolidate. Even then a bicycle can be ridden over the greater part of the beach at low tide only. A bicycle may easily be placed in a canoe and ferried across the rivers. The party found the bicycle useful in some places, notably between Aitape and Arop. At only four points on the whole of the coast-line between Smein and Sissano, a distance of 75 miles, are there headlands which bar progress along the beach.

The question of road construction across this country will be full of difficulties. In the coastal parts there are many sago swamps to be crossed, and the meanderings of senile streams will require the construction of a considerable number of bridges, or the diverting of the streams to other courses. It must be also remembered that these streams are subject to frequent floods.

The advanced dissection of the uplands also introduces engineering difficulties, which would require costly works in land lines of communication, even in a country otherwise well adapted to white settlement.

GENERAL GEOLOGY.

Summary of Stratigraphy.

The summary given below may be considered as a provisional classification of the rocks exposed within the area examined, but it probably applies to neighbouring localities also.

Recent and Pleistocene—

(1) Coastal Deposits—Estuarine and river beds, river gravels, sands, and muds.

(2) Matapau Coralline Limestone—Limestone interbedded with pyroclastic deposits and muds.

(3) Mau River conglomerate and muds.

Unconformity:—

Late Tertiary (probably Pliocene)—

(4) Aitape Beds—Approximately 5,000 ft. thick; limestone and volcanic rocks.

(5) Mendam Beds—Conglomerate, sandstone, and agglomerate. Thickness not determined.

Disconformity:—

Tertiary (probably Miocene)—

(6) Yalingi River and Ulau Beds—2,500 ft. thick. Blue micaceous mudstone, alternating shale and sandstone.

(7) Aiterap Beds—750-1,000 ft. thick. Chiefly thickly bedded mudstone.

(8) Bliri River Beds—Shale, sandstone, and limestone.

Unconformity:—

Pre-Miocene (possibly Mesozoic)—

(9) Older altered sediments—Crystalline limestone, indurated claystone, and slate.

Pre-Cretaceous—

(10) Schists and gneisses of the Main Dividing Range.

Note.—The Bliri River Beds (8) are more compact than those of (6) and of (7) and the fossil evidence suggests greater age. Possibly (6) and (7) should be placed in the Pliocene, or they should remain in the Miocene and (8) be tentatively classed as Oligocene.[5] (*See* also pages 86-87.)

(1) *Coastal Deposits.*—Apart from the muds and river gravels which form the low-lying area behind the beaches there are several points at which shell-beds have accumulated and have since been raised from a few feet to about 8 ft. above sea-level. Shell-beds are to be seen at Ulau, St. Anna Mission, Pultulul, Ulau, and Tepier Plantations.

(2) *Matapau Coralline Limestone.*—At Matapau, raised coral occurs, overlain by mudstone. In some places this sequence occurs more than once, interbedded with pyroclastic deposits. These beds rest with marked unconformity on the Miocene mudstones, and the amount of uplift indicated is about 8 ft.

(3) *Mau River Beds.*—The river-conglomerate and mud at the junction of the Yalingi and Mau Rivers rest on the eroded Tertiary rocks with marked unconformity. The beds are about 70 ft. thick. Similar beds occur in the Wiwa and other rivers.

(4) *Aitape Beds.*—The geological age of the Aitape beds is largely conjectural. The outcrops to be seen at the present day are but a remnant of a much more extensive series. The geological relationships existing between this series and other rocks in the Aitape district are entirely obscured by recent deposits. These beds are referred to the later Tertiary because they are certainly older than the Pleistocene raised coral and because of the occurrence in them of volcanic rocks similar to those found at Moron and elsewhere in New Guinea.

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[5] Oligocene and Eocene beds are said to occur on the north side of the Bewani Mountains, which adjoin the Torricelli Mountains (Aust. Ency., vol. ii., p. 25).

(5) *Mendam Beds.*—These beds are well exposed in a gorge at the head of the Pieni River. They consist chiefly of coarse sediments overlying mudstone and sandstone disconformably.

(6) *Yalingi River and Ulau Beds.*—These consist in part of sandstone and fine conglomerate with mudstone beds, and of alternating shales and sandstones. Details of this series as exposed in the Yalingi River near Waningi are given on page 80. There are also exposures of blue sandy mudstones in the Tomoflu River near Romi, and in the Oi River near Walwalli, containing fossils similar to those obtained near Ulau. Fossils are abundant in certain zones in all the exposures of these beds. The only actual surface evidence of the occurrence of oil within the area is the Lupai spring which issues from Recent mud deposits overlying the Yalingi River beds. The series is lithologically ideally adapted for the accumulation of petroleum.

(7) *Aiterap Beds.*—The Aiterap beds constitute a very thick mud series with no particular features of interest. There appear to be two facies:—

i. A lower group of yellow-brown mudstones, calcareous towards the top.

ii. An upper group of blue micaceous mudstones.

(8) *Bliri River Beds.*—These beds consist of shale, sandstone, and limestone, the latter being more abundant towards the top of the series. The limestones are fossiliferous in places. They outcrop in the headwaters of the Bliri and Wini Rivers. Possibly the limestones in the Wiwa River may belong to this group.

The shale and sandstone form a series of thin beds alternating with each other. No estimate of thickness of the series has been given, but judging by the exposures high above the bed of the Wini River it is at least several hundreds of feet.

(9) *Older Altered Sediments.*—In Bulletin XIII. of the Imperial Institute (on page 567), reference is made to the occurrence of Cretaceous beds in the Torricelli Mountains,[6] and the late Evan Stanley indicated an area of Cretaceous rocks on his geological map of the New Guinea Territory. There appears to be a group of rocks both north and south of the divide which has not been subjected to the same amount of alteration as the schists and gneisses of the Main Dividing Range. Slaty and serpentinous rocks occur on both sides of the divide, and Mr. Wilks, patrol officer, has collected slate with *augen* of quartz southwards from Yakomul.

A Mesozoic age has been assigned to similar beds in New Guinea and Papua, and may perhaps be accepted tentatively here. A verification of the existence of Cretaceous rocks may fix the age of these and similar beds quite definitely.

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[6] Also referred to in Aust. Ency., vol. ii., p. 25.

(10) *Main Range Schists and Gneisses.*—The schists and gneisses of the main range are well exposed in the headwaters of several of the rivers. These are discussed in some detail on page 83. The only geological age which can be assigned to these beds with any certainty is Pre-Cretaceous.

Description of Localities.

The geography of the area is a direct expression of the geology, and the latter may therefore be conveniently described under the headings adopted in the discussion of geography.

(1) *Coastal Plain.*—As already mentioned, there are very few outcrops to be observed throughout this portion of the area. For the most part it consists of mud and clay with some sands and river gravels.

In the vicinity of Aitape, in the hills previously mentioned, a limited number of outcrops occur, extending from St. Anna mission to a small headland north-westerly from Tepier plantation. In the St. Anna mission the outcrops consist of limestone, with thin beds of volcanic breccia. Aitape headland is made up of limestone capped by volcanic agglomerate. The agglomerate in turn appears to be overlain by a vesicular lava much traversed by veins of calcite. The upper part of the series is repeated at Pultulul, where some thin limestone beds are also included. In the headland at Tepier plantation, volcanic rocks attain a maximum and the limestone beds are insignificant. The headland consists almost entirely of a coarse agglomerate. This agglomerate is underlain by a volcanic rock of trachytic type, as is shown by the exposures in the rocks which outcrop in the sea, between Tepier plantation and the new village of Marok. It is also overlain by a lava somewhat more basic.

From its general disposition in relation to the headlands on the mainland there can be little doubt that the volcanic rocks outcrop both on the island of Tomleo and in the small islands (Ant Rock, Oyster Rock, &c.) between Tomleo and Aitape. The rocks there evidently dip in the same direction and at the same amount as those in the vicinity of Aitape —namely, S. 15 deg. E. at 20 deg. (Plate III., fig 2.)

From the above description it appears that all these rocks form part of a conformable series, in which the limestone attains a maximum thickness at Aitape and rapidly thins out laterally east and west. There are very few fossils in these beds.

The other two remaining outcrops, in the coastal plain at Malol and Sissano, consist of limestone very similar lithologically to that already described.

(2) *Coastal Foothills.*—Tertiary rocks outcrop over practically the whole of the coastal foothills. It is proposed to discuss these rocks under localities.

(*a*) *Ulau.*—Ulau is a large coastal village at the eastern end of the area examined. The Damayien River flows through part of the village and may be examined throughout the whole of its course, a distance of about 4 or 5 miles. Where the Nundrawada and Damayien meet they are already practically at base-level, and are forced to spread out again in order to carry the greatly increased volume of water which comes down from the mountains after heavy rain. They enter the sea through three distributaries, of which the easterly one is the most important.

About 2 miles from the beach and at the junction of these two streams, Tertiary rocks are exposed. They consist of andesitic lava, mudstone, and sandstone in the form of a syncline the axis of which strikes N.W. and S.E. Where these rocks abut the older rocks of the divide, they are sharply folded. (*See* Section, page 84.)

Fossils were obtained from a bed some 5 or 6 ft. thick. They were fairly abundant but difficult to secure as complete specimens. These beds are very similar in general appearance to those exposed at Matapau.

(*b*) *Nigia River.*—The Nigia River flows for the greater part of its course across Tertiary beds. The fact that a large oil seepage had existed near the village of Chinapelli and had been covered by a recent landslide could not be verified, the natives disclaiming knowledge of its existence.

Specimens of rock collected by Mr. Adam Wilks, patrol officer, from near Chinapelli, show that the divide here consists largely of the same rock types (chiefly slate with *augen* of quartz) which occur on the flanks of the main range near Lupai, and which are certainly too old and too much altered to yield anything of importance from the point of view of Petroleum Geology.

(*c*) *Kapoam District.*—In the low divide between the Nigia and Raihu Rivers, Tertiary beds outcrop in the form of sandstone, fine conglomerate, and thin beds of mudstone. The little evidence available suggests the structure of a pitching anticline with its axis approximately N.N.W. At Paiawa the rocks exposed have been completely altered to a bright red clay. The clay suggests the volcanic rocks near Aitape, and it may be that the Tertiary beds are intruded at this point.

(*d*) *Raihu River.*—In the headwaters of this large river the predominant outcrops are mudstone, with some sandy, pebbly, and tuffaceous beds, though in the upper waters of the Wiwa River prominent beds of limestone occur interbedded with mudstone. They appear to be unfossiliferous at this point. The bed dips southerly, the amount of dip being generally about 15 degrees.

In the Wiwa River near Osi the mudstone is intruded by a rock of dioritic type, and the beds are practically vertical. A sulphur spring occurs near Levaiti, and this appears to be associated with late or Post-Tertiary intrusive rocks. One may note that, at Matapau, oil seepages are associated with sulphur-bearing springs in an anticlinal structure intruded by granodiorite. Possibly there are other intrusions in the Raihu valley.

(*e*) *Aiterap-Siauti Area.*—At Aiterap a thick mudstone series outcrops. It includes a few thin beds of limestone. Many bars in the creeks in this locality are covered with a deposit of secondary limestone or tufa. Owing to the presence of marked jointing and the absence of distinct bedding planes, it is difficult to determine the dip of the beds. They appear to dip steeply to S.E., but this is not quite certain. Towards Wom (the local dialect name for Coconuts) the mudstone series becomes calcareous and in places might be described as earthy limestone. At Wom the prevailing dip appears to be southerly. In the Peli River, the mudstone, as at Ulau, is blue and micaceous and in places sandy. There are also sandstone beds which are valuable in indicating dip. The beds are folded into anticlines and synclines, the axes of which strike approximately E. and W.

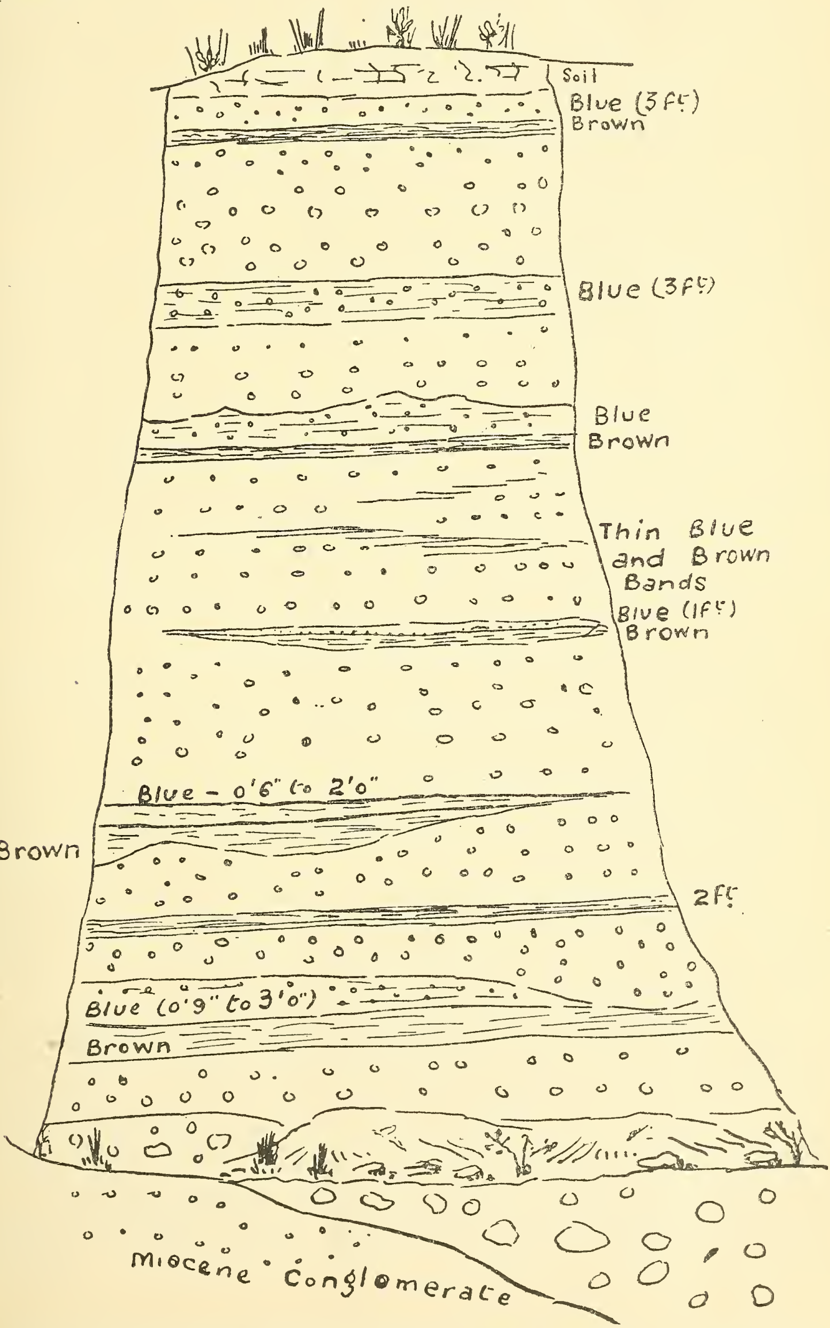
The Peli is a small stream which is lost in swamps soon after entering the coastal plain. Its deflection eastward, near Siauti, is due rather to the obstacle provided by older river gravels from the Yalingi than to adjustment to structure, as might be concluded from the map.

The natives of Wom obtain some of their salt water for cooking purposes from a brine-soak in the blue micaceous mudstones, but little importance can be attached to the occurrence of brine at this point. The water is certainly not as salt as that of many creeks which flow over marine rocks in the Permo-Carboniferous system of New South Wales. Upstream, sandstone beds become more numerous, and there are several beds of fine conglomerate which amount in some places to quartz-conglomerate.

(*f*) *Yalingi River.*—The Yalingi River in part of its course reveals a somewhat similar section to that exposed in the Peli, but the Yalingi is a large stream and the information is more complete.

The Yalingi River flows practically due south for a distance of 8 or 9 miles, exposing a section of Tertiary rocks. The lowest members of the rocks exposed consist of the blue micaceous mudstone, previously mentioned. These beds are traceable to a point in the river about 1 mile south from the new village of Waningi, where sandstone beds are to be seen (dips: S. at 19 deg., and S.W. at 12 deg.). Sandstone and mudstone in alternating beds 2 to 16 in. thick form the outcrops to about a mile upstream from Waningi. An excellent section some 35 ft. high is exposed by a waterfall close to the main stream. Fragments of fossils obtained resemble those from Ulau. Sandstone and fine conglomerate overlie this stage. (Plate IV., fig. 2.)

The structure is that of an asymmetrical anticline, which dips steeply on the northern side of the axis and more gently (12 to 20 deg.) on the southern. This structure is modified by a bulge or low dome near Waningi. At Lupai, mudstones outcrop, dipping 8 deg. N. These are also interbedded with sandstone. A syncline is indicated between Lupai and Waningi. South from Lupai a second anticline is developed more nearly symmetrical and more gently dipping than the first. The dip rapidly increases from 7 deg. near Lupai to 25 deg. in the Mau River. At the junction of the Mau and Yalingi Rivers an excellent section of Pleistocene or Post-Tertiary beds is exposed by a landslip. These muds and river conglomerates form a vertical face about 70 ft. high, and they rest on the eroded edges of Tertiary rocks. The following section is exposed:—



Section of Post-Tertiary Muds and Gravels—Junction of Mau and Yalingi Rivers.

R.S.—F Height, 70 feet. Approximately to scale.

It will be noted that pebbles occur throughout the section, but that they are less abundant and smaller in size in the mud-layers. Nearly all the mud-layers exhibit the same characteristics—namely, a brown mud at the base overlain by a blue mud with small pebbles towards the top. There are in all eight pairs of blue and brown muds which vary in thickness from 9 in. to 3 ft. (Cf. Plate IV., fig. 1.)

To examine the causes giving rise to this section, in detail, is beyond the scope of this paper, but some suggestions may be made. There is evidently some rhythm to be considered. The blue (or grey) beds probably owe their colour to iron disulphide; the brown, to mixtures of hydrated ferric oxides; indicating that the former have been subject to marine (anærobic) conditions sufficiently long to enable conversion of the hydrous oxides into sulphides. The gradual change from marine to shore-line or terrestrial conditions is indicated by the presence of pebbles in the mud-layers overlain by conglomerate.[7]

(*g*) *Pieni and Nengo Rivers.*—In the Nengo River the mudstones are underlain conformably by volcanic agglomerate (dip, E. 20 deg. S. at 50 deg.), which is therefore the lowest bed in this section of the Tertiary sediments. Mudstones outcrop throughout the lower part of the course of the river, interbedded with thin strata of limestone and tuff. About 2 miles above the junction of the Numella and Pieni, sandstone and conglomerate beds make their appearance. The junction appears to be disconformable, and the beds above the disconformity are different from anything previously observed. The conglomerates are much coarser, and there are occasional beds in which the fragments are angular. The latter become more and more numerous higher in the series, and the final stage is dominantly agglomeratic.

It will be noted, by reference to the map, that the maximum folding is at the northern end of the section, which indicates that the folding force was directed against the beds from that quarter.

(*h*) *Bliri or Raimbrum River.*—This river is the largest on the Aitape coast. A glance at the map will show that for a distance of 12 miles from its mouth the river flows through a low-lying area of jungle and swamps.

The mountain at Barida is composed almost entirely of mudstone. There are a few sandstone and limestone beds. The occurrence of tufa deposits derived from the latter may also be noted. The beds dip to S. and S.W. at angles which vary from 27 to 45 degrees.

In the Neni River, near Romi, sandstone and fine conglomerate outcrop, and at the junction of the Ebleli and Bliri Rivers the limestone bed in this section is in evidence. Thence the section to Karandu exposes mudstone, sandstone, and limestone, the latter more and more strongly marked as the river is ascended. It is compact and non-fossiliferous, and the exposures strongly suggest the Wiwa River section near Osi.

[7] *See* Twenhofel, "Treatise on Sedimentation," 1926, pp. 543-550, for general statement and for further references.

Immediately above Calau the Tertiary rocks are intruded by igneous rock, steeply folded, and, in places, somewhat altered. So far as can be seen the intrusion appears to be sill-like in type.

Below Morlu interbedded sandstones and shales outcrop in the river bed. The bedding planes are practically vertical. Between Morlu and Durali only river gravels are to be seen. These contain numerous pebbles of coralline limestone, of Tertiary age, derived from the foot of the main range above Durali. There must be a considerable thickness of these gravels corresponding to the rocks of Post-Tertiary age at the head of the Yalingi River. (*See* also "(4) *Inland Slopes.*")

(3) *Dividing Range.*—The Dividing Range is composed for the most part of altered rocks of both sedimentary and igneous origin.

After leaving Mendam one passes over crystalline limestone and indurated claystone. The central portion of the range is composed of schists intruded by a rock of dioritic type. The latter is in turn intruded by porphyry. On the southern side of the divide the road leads over thick beds of crystalline limestone for some distance. Here again fossils appear to be absent.

At the head of the Mau River, above Lupai, the Tertiary beds rest unconformably against a series composed of gneissic rocks of great variety. Acid types with basic *schlieren* are of common occurrence. A thick band of dull red jasper, traversed by numerous veins of quartz, was also noted.

The southern side of the divide (Wapi) consists largely of altered sediments, chiefly schists with many isolated lenses of quartz.

All the original characters of these beds have been destroyed. It is certain they are Pre-Tertiary in age. The more highly altered may be Pre-Cretaceous, but the criterion of degree of alteration is capable of leading one into great error, and its value in the determination of geological age in New Guinea has been much over-estimated.

(4) *Inland Slopes.*—In the headwaters of the Bliri River, near Maiwetti, there is exposed a considerable thickness of Tertiary beds. In places fossils are abundant, though largely fragmentary. The beds from which the fossils were obtained vary from mudstone to sandy shale. These are overlain by tuffs, grits, and conglomerates.

Similar beds outcrop on the path between Maiwetti and Yongiti. In the Wini River, below Yongiti, shales interbedded with sandstones are exposed. At one point a landslip reveals a face 50 ft. high which is made up of four sandstone beds 2 ft. thick, separated by beds of shale 10 to 12 ft. thick.

All the rocks exposed in this portion of the area dip relatively gently, and they present many features in common with beds on the northern side of the divide. They appear to be somewhat more compact, however.

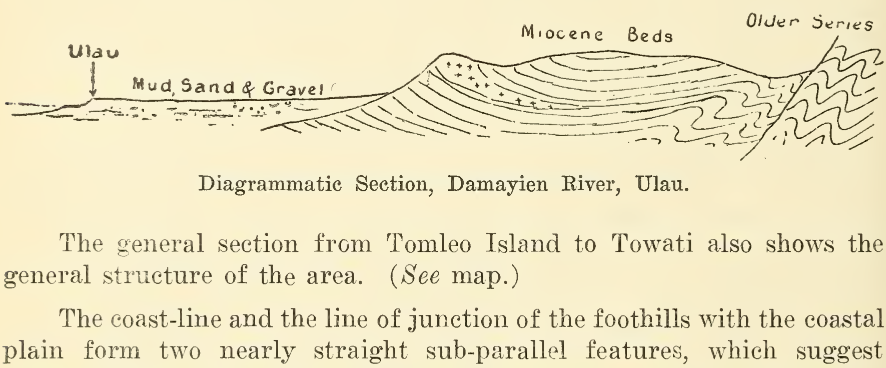
Structure.

The structure of the area is not complex. It will be seen by reference to the map that the geology is such as to preclude a very close analysis of folding movements during Tertiary time.

The relationships existing between the Aitape Series and the Miocene beds of the coastal foothills is not likely to be made out in the field without the assistance of information obtained from bores, and in the absence of detailed palæontological evidence the relative age of these beds and the movements affecting them must remain in doubt.

The main folding movements, of which there is undoubted evidence, took place in Post-Miocene or Late-Miocene time. The Tertiary beds both north and south of the divide exhibit similar structures, and appear to have been subjected to the same fold movements, although possibly not to the same degree.

The folding of the rocks is directly related to the uplift of the mountains which extend sub-parallel to the coast-line. The main axis of folding extends W.N.W. and E.S.E., and the intensity of folding decreases from the mountains, seawards, and from the mountains towards the Sepik River. The following diagrammatic section at Ulau may be taken as typical for both north and south sides of the Main Dividing Range:—



Diagrammatic Section, Damayien River, Ulau.

The general section from Tomleo Island to Towati also shows the general structure of the area. (*See* map.)

The coast-line and the line of junction of the foothills with the coastal plain form two nearly straight sub-parallel features, which suggest faulting. There is no direct evidence of this, but as each of these features has been developed in, at the oldest, Post-Miocene time, and is in turn approximately parallel to the main coastal range, faulting is at least suggested.

Geological History and Physiography.

It is fairly evident that, in Tertiary time, very little of the present land surface was above the sea. Probably the older metamorphic series emerged as a line of narrow islands. The limits of this sea lay beyond the area examined north and south of the Main Dividing Range.

The thick mud-series which occurs at Aiterap and other places suggests deep, still water. A period of uplift followed, the mud-beds being overlain by marine and deltaic deposits consisting characteristically of blue, micaceous, and sandy mudstone. Fairly regular rhythms in the general uplifting movement are indicated, giving rise to the Yalingi River shale and sandstone series.

Subsidence followed this uplift, and during this time the limestone beds of the Aitape series were laid down. The succeeding phase introducing volcanic rocks seems to have been very widespread, and took place in Late-Tertiary time.

Following the outpouring of these lavas a considerable amount of uplift is indicated, for the limestones which underlie the volcanic rocks stand at a considerable elevation with reference to the newer coralline limestone assigned to a later period of subsidence.

Probably in Late-Pliocene time (or even Pleistocene) depression followed elevation, coralline limestone being formed in the resultant clear water. In the headwaters of several of the larger rivers sections are exposed up to 70 ft. in thickness of muds and gravels which rest unconformably upon Miocene beds. These beds were probably laid down at the same time as the new coral-beds. The following uplift in the main divide resulted in the formation of consequent streams flowing northwards to the sea.

It cannot be said that the present coastline shows everywhere signs of recent emergence. In the Matapau area coral-beds occur 8 ft. above sea-level; at Aitape they form wave-cut benches at half-tide level; while the features presented at Vanimo seem to indicate drowning as the result of the latest movement.

In the St. Anna mission plantation there is a beautifully preserved raised beach which extends between two limestone bluffs. These bluffs mark former headlands and exhibit unmistakable evidence of undercutting by wave action. The fossil beach is about 250 yards from the present shore-line, but it is not more than 6 or 7 ft. above mean tide mark. Similar former beach-lines are indicated at Pultulul, Ulau, and Tepier plantations. Practically all the coastal streams show deserted channels filled with gravel, and recent land-uplift is indicated by deep dissection and the existence of waterfalls.

At Aitape, however, where our base camp was built, the coralline limestone is practically at sea-level. Pebbles which are found in the coral about 4 ft. below the surface have been derived from the volcanic rocks in the adjacent hills. This indicates some degree of subsidence. At the Sissano Lagoon subsidence appears to have taken place within recent historical time.

The Warapu people, invaders from the Wanimo district, originally lived about the mouth of the lagoon, but the sea broke through and forced them to find a new home. Dead trees and lines of coconut stumps give some indication of the former drainage. It is difficult to account for the fact that coconut palms on the seaward side of the lagoon have also been submerged, if subsidence has not taken place. The amount of subsidence indicated is about 6 ft. (maximum), and the date of the event about twenty years ago. (Plate III., fig. 1.)

Palæontology.

The following notes have been supplied by Mr. Tom Iredale, of the Australian Museum; locality names in brackets have been added by the writer:—

"The specimens submitted included some separate casts, some pieces of limestone, coral rock, and some mudstone samples.

"The separate casts were all from 15 miles south of Yakomul, and comprised *Arca sp., Circe sp., Clementa sp., Placuna sp.*, and apparently *Conus* and *Voluta spp.* They were all of similar facies to the recent fauna from the neighbourhood.

"The limestone coral rock from Pultulul village shows the impression of an *Arca* valve, very much like one of the recent species. Another piece of limestone coral rock (from near Leitre village) shows impressions of species of *Cardium*, very like the recent *Flavum* group.

"There are five lots of mudstone, all agreeing in general appearance and showing numerous shell fragments, but solution only gave more, no complete shells dissolving out, and those apparently perfect breaking up, indicating great pressure. Of these lots No. 5 showed an *Oliva sp.*, a *Turritella sp.*, and a species of *Mitra* very like recent shells. In No. 8 a species of *Pyramidella* was distinguishable; in No. 31 an *Oliva* like the previously named one could be seen. [These came from the beds at Ulau shown on the section on page 84.]

"In No. 33 the *Turritella* again recurred and a *Pecten* impression was observed. [Oi River near Romi.]

"No. 25 was a specimen of muddy appearance but harder texture, showing a bivalve which might be a small *Crassatellites* and a gastropod of Cerithioid affinity, but apparently young and broken. This lot may be older than the preceding, and the species are not so obviously of recent form. [Bliri River, near Maiwetti, south side of main divide.] No. 29 [from Durali] showed two pieces of corals.

"It will be seen that the mud-series do not suggest great age, and probably perfect specimens of the molluscs represented could be reconciled with the Recent fauna. The first-named casts may be older, and No. 25 much older."

Mr. W. S. Dun, who also examined these fossils, states that they may be considered as either Pliocene or Miocene. However, there are other factors which may be considered.

Orbitoides limestone occurs at Matapau, about 10 miles east from Ulau, where some of the fossils described above were obtained. The age of the former occurrence is Miocene. The beds at both these localities are very similar lithologically, and on palæogeographic grounds cannot be very different in age.

Further, the raised coral-beds throughout the Mandated Territory are generally assigned to the Pleistocene (*see* Evan Stanley's map). The Aitape Series is certainly older than these, and is, therefore, probably Pliocene. The beds of this series are also very similar to beds which occur in other parts of the Territory, to which a Pliocene age has been allotted. The fossiliferous beds in turn are certainly not younger than the Aitape Series.

From this we may conclude (tentatively at least) that the Matapau and Yalingi Beds are generally of the same age, namely Miocene, although they may possibly be referable to different stages within that series.

ECONOMIC GEOLOGY.

General.

When one has stated that the greater part of the area is covered with Tertiary rocks, it is obvious that there are not likely to be a great number of economic minerals awaiting development.

The altered and igneous rocks of the main divide possibly contain metallic deposits of importance. Apparently no deposits have so far been located in this region, but the recent discovery of gold at Edie Creek, on the Markham River, in an area similarly situated, may encourage prospectors to go farther afield. Prospecting would present very little difficulty, as the dividing range may be reached in no more than two days' journey from Aitape.

There appear to be ample shale and clay available for the manufacture of bricks, tiles, earthenware, and other similar materials. The natives of Tomleo Island have been making pottery for many years from a bright-red clay (derived from the decomposition of andesitic lava) which they obtain from the mainland directly opposite the island.

The coastal limestones have also been used for the manufacture of lime by local mission stations. The natives themselves burn shells and coralline limestones for lime which they chew with the betel-nut.

Petroleum.

In the search for oil in a new region it is important to review the factors which affect the occurrence of oil. There are a number of considerations which are essential to the accumulation of oil-pools, but there appears to be no general agreement upon the relative importance to be given to individual factors. The essential conditions may be briefly stated as follows:—

1. A source from which the oil may have been derived;
2. Sedimentary rocks of sufficient thickness, suited lithologically to the storage of oil;
3. Suitable geological structures to constitute an oil reservoir;
4. Absence of intense metamorphism;
5. Suitable water-conditions.

In applying these conditions to the geology of the Mandated Territory the absence of detailed information is at once apparent.

It seems hardly possible to doubt that there has existed a source from which oil could have been formed. The geological history of the region indicates this. There are also seepages of oil at various places along the Aitape-Madang coast, and small quantities of oil have been obtained by boring at Matapau. Several brine springs giving off the odour of petroleum occur in the Aitape district.[8]

It seems that the existence of productive oil-fields in the East Indies (Borneo and Ceram, for instance) effectively disposes of the criticism, based on a consideration of climate, that a "barren equatorial"[9] belt exists, but there are undoubtedly good reasons, from a consideration of tectonic geology, that oil-fields in such regions may be restricted in area.

It is not likely that oil will be won in the Mandated Territory from rocks older than Tertiary. Tertiary rocks occupy the greater part of the coastal plain and foothills (overlain in places by Pleistocene and Recent rocks) and a considerable part of the inland slopes. Evan Stanley states[10] that "Plio-Miocene, foraminiferal mudstones, and carbonaceous sandy mudstones are known nearly 200 miles up the Ramu, whilst further west they occupy valleys in the Eocene and Mesozoic deposits."

From verbal information supplied by Dr. H. I. Jensen, and Messrs. Winters and Lindsay, who have visited different parts of the Aitape, Madang, and Sepik districts, and from personal examination, it is apparent that there is a large extent of Tertiary rocks in the coastal area and in the Sepik and Ramu River valleys. A correlation of this scattered information is very desirable.

The main divide consists of highly folded and altered rocks, and it is understood that igneous and metamorphic rocks occupy portion of the Lower Sepik (verbal information, Dr. Jensen). These areas cannot possibly be regarded as oil-bearing. Surface indications of the occurrence of oil are evident only in areas occupied by Tertiary rocks, which also in other parts of the East Indies are oil-bearing. Probably beds of Miocene age are the only ones which need receive consideration in a preliminary examination.

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[8] Attention may be drawn to the supposed seepage of oil at Leitre. (Evan Stanley, "Salient Features of New Guinea," p. 67.) Mr. Hanlin, who accompanied me in some of the New Guinea work, visited Leitre, and from verbal information supplied by him it seems likely that the seepage (so called) is not always to be seen, and when apparent appears to be rather a ferric hydroxide film.

[9] M. G. Mehl, Bull. Sci. Lab. Denison Univ. 1919, vol. 19, pp. 55-63.

[10] Evan Stanley, "Oil Provinces in New Guinea," Proc. Pan-Pacific Science Cong., vol. ii., 1923, p. 1249.

Tertiary rocks attain great thickness, and in the Aitape district they certainly exceed any suggested possible minimum for productive oil-fields.

Over wide areas, also, interbedded shales and sandstones occur, overlain by a considerable thickness of mudstone, and porous "sands" have also been encountered in drilling.

From a consideration of palæogeography it will be seen that the Miocene beds were probably laid down close to an old land mass where a good deal of variation in the physical character of the sediments might be expected, and where sands could accumulate free from the deposition of mud and clay which might close the pore-spaces between the sand-grains.

The structural geology indicates that over fairly large areas the Tertiary beds have been but gently folded. From this point of view the beds in the inland slopes are possibly more likely to yield suitable structures, but a greater degree of certainty of obtaining oil would need to exist before prospecting that region in preference to others more accessible.

In some places the Tertiary beds have been strongly folded and intruded by igneous rocks of granodioritic type, chiefly in the form of sills. These areas might also be eliminated in a preliminary examination, but as seepages of oil are abundant in such localities important information may be gained as to actual oil horizons.

The report of the geologists of the Anglo-Persian Company (as summarised by the late Evan Stanley) is somewhat misleading in its reference to the country inland and west from Aitape. The highly altered and intruded Tertiary beds described by them are not typically developed farther west on the New Guinea coast than Matapau.

It is impossible to forecast the water-conditions likely to be met with in drilling. In other parts of the East Indies oil has been won from anticlinal structures, presumably from wet sands, and a similar condition may be expected in New Guinea. On the other hand, verbal information seems to indicate that the beds bored through at Matapau and the lower Sepik have been relatively dry. If this is so, the possibility of the oil occurring on the flanks of anticlines or in synclines should be investigated.

In a short review of the conditions such as has been given, many points of interest have not been mentioned, but from what has been written it will probably be admitted that all the factors which need to be considered in an oil-field reconnaissance are present on the mainland of New Guinea. The search for oil might well be confined, in the first place, to locating suitable structures in beds of Miocene age, which have not been too highly folded or much intruded by igneous rocks.

REFERENCES.

1. Australian Encyclopædia, vol. ii., 1926, pp. 22-31.

2. Bulletin Imperial Institute, ''Economic Resources of the German Colonies,'' vol. xiii., No. 4, 1915, pp. 559-581.

3. L. V. Dalton, ''On the Origin of Petroleum,'' Economic Geology, vol. 4, 1909, pp. 603-631.

4. David T. Day, ''The Conditions of Accumulation of Petroleum in the Earth,'' Trans. Am. Inst. Min. Eng., vol. xli., 1911, pp. 219-224.

5. Leaflets of the Department of Agriculture, Territory of New Guinea.

6. M. G. Mehl, Bulletin of Science Laboratory, Denison University, vol. 19, 1919, pp. 55-63.

7. Evan Stanley, ''Salient Geological Features and Natural Resources of the New Guinea Territory,'' 1922.

8. Evan Stanley, ''Oil Provinces in New Guinea,'' Proc. Pan. Pacific Sci. Cong., vol. ii., 1923, pp. 1249-1252.

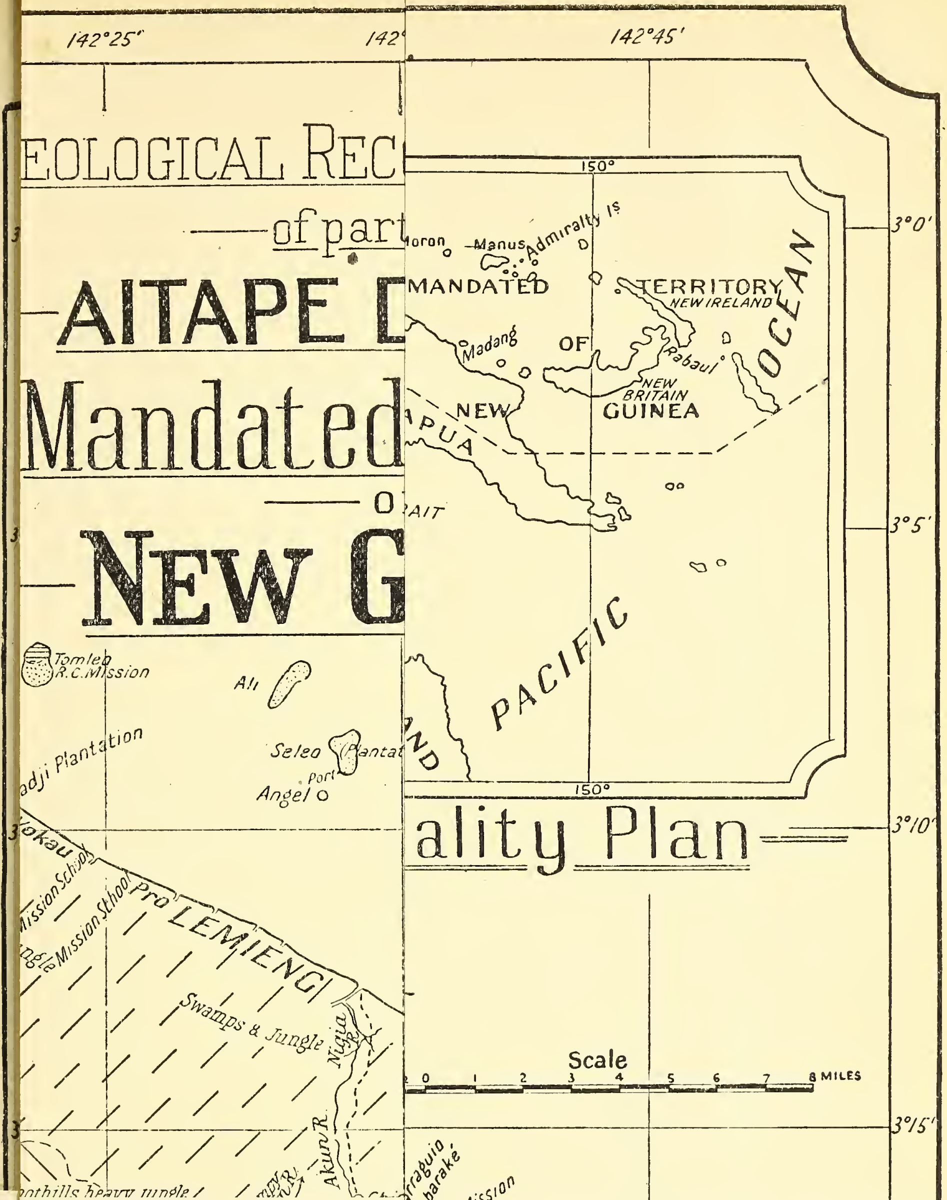
9. Murray Stuart, ''The Geology of Oil, Oil-Shale, and Coal,'' 1926.

10. William H. Twenhofel, ''A Treatise on Sedimentation,'' 1926.

11. David White, ''Some Relations in Origin between Coal and Petroleum,'' Jour. Wash. Acad. Sci., vol. v., 1915, pp. 189-212.

12. David White, ''Late Theories regarding the Origin of Oil,'' Bull. Geol. Soc. America, vol. 28, 1917, pp. 727-734.

13. David White, ''Genetic Problems affecting the Search for Oil in New Regions,'' Trans. Am. Inst. Min. Met. Eng., vol. lxv., 1921, pp. 176-195. (Contains also many other useful references.)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Tomleo R.C. Mission
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Port Angel
Swamps & Jungle
Nigia R.
Akun R.
Mission School
Jungle Mission School
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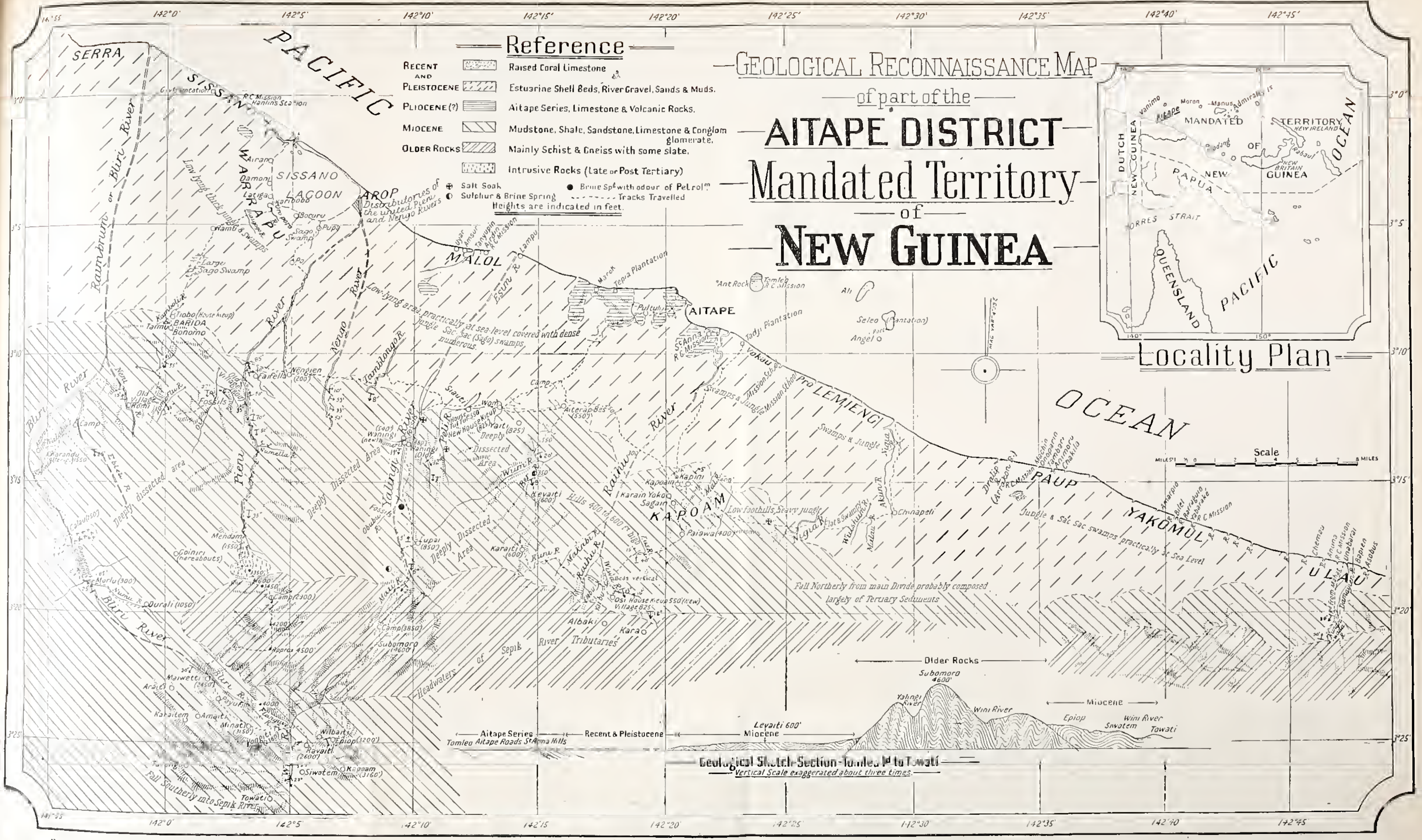

Reference
Recent and Pleistocene
Raised Coral Limestone
Estuarine Shell Beds, River Gravel, Sands & Muds.
Pliocene (?)
Aitape Series, Limestone & Volcanic Rocks.
Miocene
Mudstone, Shale, Sandstone, Limestone & Conglomerate.
Older Rocks
Mainly Schist & Gneiss with some slate.
Intrusive Rocks (Late or Post Tertiary)
Salt Soak
Sulphur & Brine Spring
Brine Spg with odour of Petrolm
Tracks Travelled
Heights are indicated in feet.
Geological Reconnaissance Map
of part of the
AITAPE DISTRICT
Mandated Territory
of
NEW GUINEA
Locality Plan
DUTCH NEW GUINEA
MANDATED
TERRITORY
OF
NEW GUINEA
PAPUA
TORRES STRAIT
QUEENSLAND
PACIFIC
OCEAN
PACIFIC
OCEAN
SERRA
SISSANO
SISSANO LAGOON
WARRAPU
AROP
MALOL
AITAPE
LEMIENG
PAUP
YAKOMUL
ULAU
KAPOAM
Rambrum or Bliri River
Nengo River
Raihu River
Low lying thick Jungle & swamps
Low-lying area practically at sea-level covered with dense Jungle Sac Sac (Sago) swamps numerous.
Swamps & Jungle
Jungle & Sac Sac swamps practically at Sea Level
Deeply dissected area
Deeply Dissected Area
Hills 400 to 600 ft high
Low foothills, heavy jungle
Fall Northerly from main Divide probably composed largely of Tertiary Sediments
Headwaters of Sepik River Tributaries
Fall Southerly into Sepik River
Scale
Older Rocks
Miocene
Aitape Series
Recent & Pleistocene
Subomoro 4600'
Geological Sketch-Section - Tumleo Id to Towati
Vertical Scale exaggerated about three times.

Fig. 1.—Coconut Palm Stumps in the Sissano Lagoon, indicating recent subsidence. The stumps indicate the banks of drowned streams. Barida hills in the distance.

Fig. 2.—Andesitic Lavas near Tepier Plantation, showing inland (southerly) dip. Tomleo Island in the distance.

Face page 90.]

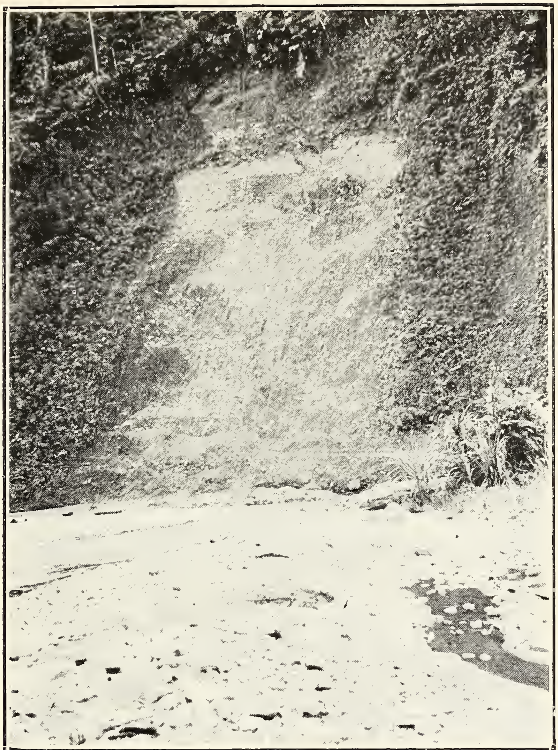


Fig. 1.—Cliff, 70 feet high, of Post-Miocene Muds and Conglomerates, at the junction of the Mau and Yalingi Rivers. (Cf. Fig. p. 81.)

Fig. 2.—Miocene Beds (alternating thin beds of Shale and Sandstone) in the Yalingi River near Waningi. Southerly dip.

Face page 90.]

Fig. 1.—Yalingi River at Lupai, showing wide gravel bed and comparatively narrow stream channel. Trees left by recent flood at left.

Fig. 2.—Torricelli Mountains, looking south-west from Waningi, showing advanced dissection. Yalingi Valley at left.

Face page 90.]

Notes on the Breeding Habits of Culex Fatigans Wied., and its Associated Mosquitoes in Queensland.*

Plates VI. and VII.

By R. Hamlyn-Harris, D.Sc., City Entomologist, Brisbane.

(*Read before the Royal Society of Queensland, 24th September, 1928.*)

The vagaries of *Culex fatigans* Wied. (*Culex quinquefasciatus* Say) are particularly noticeable and interesting during such extensive control operations as are at present in vogue in the Greater Brisbane area. This species is the commonest night-feeding mosquito in Brisbane. It prefers larger and more permanent areas of polluted waters, when it can get them, than might appear to be the case from its domestic habits of breeding in small household receptacles. When *Culex fatigans* gets a firm hold of any locality, it is enlightening to follow its methods of making the most of every available scrap of polluted water, and the selection of breeding places, both elective and compulsory as the case may be, follows not only as a natural consequence but as an imperative necessity. As a result of this adaptive characteristic, the associations with other mosquitoes are most marked; the following are frequent:—

1. *Anopheles* (*Myzomyia*) *annulipes* Walker;
2. *Aedes* (*Stegomyia*) *argenteus* Poiret (*A. ægypti* L. Dyar), (*Stegomyia fasciata* Fabr.);
3. *Aedes* (*Finlaya*) *notoscriptus* Skuse;
4. *Lutzia halifaxi* Theo. (*Culex tigripes* Grandpré);
5. *Culex annulirostris* Skuse;

and those found less frequently are—

6. *Mucidus alternans* Westwood;
7. *Aedes* (*Ochlerotatus*) *vittiger* Skuse;
8. *Aedes* (*Ochlerotatus*) *vigilax* Skuse;
9. *Aedes* (*Finlaya*) *alboannulatus* Macq.

ASSOCIATIONS WITH *AEDES ARGENTEUS*.

Hitherto the occurrence of this mosquito with *Culex fatigans* has always been regarded as a sign of pollution, but, as the number of such associations in this area is on the increase, it may be that this occurs owing to the preferential breeding places being reduced in number.

* From the Entomological Section of the Department of Health, Brisbane City Council.

When these two mosquitoes are found together in a rainwater tank, a practice of submitting such findings to a closer scrutiny is always made, but only in a few instances was it possible to prove pollution.

During the summer of 1927-28 this association became more frequent still, not merely in unscreened rainwater tanks but in all sorts of water-holding rubbish about human habitations. Disused paint tins in which paint brushes are found soaking, some of which have a lingering smell of turpentine, are a fruitful source of supply. Any characteristic "hay infusion" aroma acts as a lure for *A. argenteus* (Buxton, 3), and *C. fatigans* is frequently found in company with it. The frequent association of *C. fatigans* with *A. argenteus* and *A. notoscriptus* in cemetery jars having this unmistakable "hay aroma" is capable of enormous possibilities (Hamlyn-Harris, 8). H. R. Carter (5) has stated—"We have not found this mosquito (*Aedes* (*Stegomyia*) *ægypti*) breeding, in nature, completely, that is, from oviposition to imago, in any collection of water, all the sides of which at the water's edge were of mud." Our own experiences correspond with this.

Knab once found *Aedes argenteus* in a small waterhole in a street in a Central American town, but Carter explained this on the supposition that the puddle was formed of water poured from some domestic vessel. Quite one of the most important associations which has come to our notice during recent years is that of the occurrence of *Aedes argenteus* in an artificial pool of water lying on the ground under a house in the city area with *C. fatigans* associated with it (pH 6.4). This occurrence, so contrary to our usual findings, was at first difficult of explanation, but on further investigation it transpired that *A. argenteus* was breeding in a section of the roof guttering of the house, and that after rain the overflow pipe carried the water directly into a small drain. At some time or other the children of the house had connected this drain with one of their own making, which led the water from one side of the house to another to a pool made formidable enough to enable them to sail their small craft. Soon after, the house was closed up for the Christmas vacation and the pool was left entirely undisturbed until found.

As far as our experience goes, such a breeding place has never been recorded for *Aedes argenteus* in Queensland before, though there are two instances on record of this mosquito breeding in the first place in a flower pot, and in the second in a tin containing ferns, both of which had during the rainy season become filled with water; the soil having set did not allow the water to percolate through, and in each case there was about half an inch of water above the coarse particles in the receptacle, most of the finer soil having been washed away. Both these breeding places were quite close to the house and were situated among dense foliage in a bush-house.

ASSOCIATIONS WITH *LUTZIA HALIFAXI.*

This "cannibalistic" mosquito occurs in Brisbane only during the summer season, though Bancroft says that it is to be found all the year round; this is not so in our experience. We find it to be essentially a warm-weather mosquito occurring only during the hottest months in the year. It was particularly plentiful during the first three months of 1928, and was seldom found unassociated. Its association with *C. fatigans* was the more usual, though it occurs also in company with *A. annulipes* and *A. notoscriptus* in such places as freshly filled kerosene tins of water left lying about the garden, places which after rain incidentally contain numbers of Chironomid larvæ. This kind of association seems unusual, for *Lutzia halifaxi* is for the most part a foul-water breeder like *C. fatigans*. *Lutzia halifaxi*, however, becomes an easy prey to over-pollution, and it is astonishing how quickly larvæ of this species die when kept in artificial receptacles not properly aerated. *Lutzia halifaxi* associates with *A. argenteus* in comparatively clean water, in horse-troughs, and such-like places.

ASSOCIATIONS WITH *ANOPHELES ANNULIPES*.

Associations with *Anopheles annulipes* occur mostly in vessels containing clean water. Household rubbish of all kinds recently filled by rain will breed such an association. Such receptacles, either artificial or otherwise, particularly rich in Infusoria and Algæ, are usually availed of. As is to be expected, such an association is not confined to vessels, but occurs equally well in waterholes in which a suitable food supply occurs. *C. fatigans* will not, however, associate with *A. annulipes* unless pollution is present even if only to a slight degree, and the hydrogen ion concentration of the water in such a case is found to be in the region of neutrality, or on the acid side of neutrality. This is rather significant in view of the fact that all the highly polluted areas of Brisbane yield a pH usually well over 8.0, but *A. annulipes* does not apparently associate with *C. fatigans* under such conditions.

ASSOCIATIONS WITH *CULEX ANNULIROSTRIS* AND *AEDES ALBOANNULATUS*.

These two mosquitoes have frequently been found together, and therefore, if under certain favourable conditions *C. fatigans* by reason of its ubiquity is found associated with them, it should occasion no surprise. These mosquitoes breed in fresh waterholes and swamps, sometimes in prodigious numbers with *A. annulipes* along the edges of the same. Such swamps are subject to degrees of pollution on account of cattle and horses; the pH of the water is usually found to be in the region of 6.5. The occasions on which such associations occur are comparatively rare and are dependent entirely on *local* conditions, it being during times of drought that such take place. Interesting cyclic variations occur frequently. One chosen from among many, considered worthy of note, occurred during the winter months of 1926.

(1) *C. annulirostris*, (2) *A. alboannulatus*, and (3) *Anopheles annulipes* were found associated together in a large waterhole which formed a portion of a natural watercourse at St. Lucia. This waterhole was filled with *Nitella myriotricha* Kütz, a great deal of which lay on

the surface of the water and was completely covered with a ferric oxide deposit; the pH hardly varied at all, but remained in the region of 6.6 all the time that the place was under observation. During a spell of dry weather in the late summer *Nitella myriotricha* still subsisted but in smaller quantities, and only *Anopheles annulipes* remained of the three original mosquitoes. *C. fatigans* selected it in the meanwhile on account of its elective breeding places becoming dried up.

ASSOCIATION WITH *CULEX ANNULIROSTRIS* AND *ANOPHELES ANNULIPES*.

The question of alternative breeding in pools and larger waterholes is rather interesting, and produces sometimes unlooked-for associations. During the last twelve months a number of such waterholes were selected for regular observations; inspections were made once a month and the results noted. Sylvan mosquitoes mostly bred in these waters, but the presence of *C. fatigans* always coincided with temporary pollution, and the commonest associated mosquitoes were invariably *A. annulipes* and *C. annulirostris*. In many of these waterholes ideal conditions exist as long as the pH remains in the region of 7; various aquatic plants are found, and the presence of large numbers of predaceous insect forms is doubtless responsible for the fact that for long periods of time mosquito larvæ are extremely scarce.

In one permanent salt waterhole, which was covered only at high tides but which dried up periodically, an interesting alternation of *Aedes vigilax* and *Aedes alboannulatus* was noticed; the association of such forms with *C. fatigans* is not unknown, but is of very rare occurrence according to the preponderance of either salt, brackish, or fresh water. When the volume of water in these waterholes is greatly increased by heavy rains, breeding seems to be temporarily arrested, and then *C. annulirostris* and *A. annulipes* seem to be the first mosquitoes to take possession and continue to flourish until pollution becomes too pronounced, and then *C. fatigans* holds undivided sway.

C. FATIGANS AND BRACKISH WATER.

It is only very rarely that this mosquito is found breeding in brackish water, and when it is, it is probably accidental. *C. fatigans* occurs sometimes in polluted tidal creeks after heavy rains, but these mosquitoes disappear after exceptionally high tides. An association of *C. fatigans* with *Mucidus alternans* does not occur very often. Along the coast and within a few feet of the sea *A. vittiger* and *M. alternans* associate frequently in comparatively fresh water, but though *C. fatigans* has been taken in association with each individually it has not so far been taken in the company of both. *A. vittiger* usually prefers an acid water (pH 6.4 or thereabouts), but such is not selected preferentially by *C. fatigans*. Cyclic alternations are bound to occur and are comparatively frequent in Southern Queensland. Some interesting instances are shown in Figs. 1-5 illustrating this paper.

HYDROGEN ION CONCENTRATION.

Although at times *C. fatigans* behaves as an acidophyle, in our experience it more frequently prefers alkalinity. Its principal breeding places as a rule have a pH ranging from 7.4 to 8.6, and one is inclined to believe that it is in this state of concentration that the food suited to the species is most likely to occur. Water contained in drains, cemented sewers, gully-traps, and other polluted waters from household refuse generally have such a pH. Whether breeding mosquitoes or not they contain plentiful supplies of organic waste and are, almost without exception, highly alkaline. If, by experimentation, the pH is swung to an acidity in the region of 5.0, the death of the larvæ and pupæ soon follows.

In the laboratory, feeding the larvæ on bananas proved a fairly successful method of swinging the pH from alkalinity to acidity. At first the larvæ thrived, but only for a short time, for the development and subsequent action of decomposition products followed soon after. In one experiment in which distilled water was used the larvæ died in a pH 5.0, and in another in tap-water in a pH of 5.4.

HIGH MORTALITY AMONG LARVAL AND PUPAL FORMS.

Larvæ of *C. fatigans* are particularly prone to suffer from a type of "intoxication" induced by the decay of food present, to say nothing of the "corpses" of their companions upon which they feed. Such "intoxication" is always more in evidence in artificial containers. During the hot summer months the mortality of thousands of larvæ and pupæ is particularly noticeable in some of our Brisbane cemeteries where the hot sun beats down on totally unprotected graves. Such water is usually alkaline. It is probable, too, that large quantities of CO_2 are evolved from the decaying matter contained in the vases, and, from the general behaviour of the larvæ and pupæ in particular, slow poisoning of some sort is apparent. The death of all pupæ in such containers is particularly noticeable. CO_2 is capable of acting as such a narcotic poison. Retardation of development is common under laboratory conditions. Poisonous excretory matter might contribute to such a result (see Williamson, 11).

The abnormality which occurs during the summer months, in cemeteries, suggests that larvæ and pupæ are dependent upon both atmospheric and dissolved air. This particular phase is worthy of further investigation.

When natural food does not suffice there is little doubt that *C. fatigans* becomes cannibalistic. In carefully prepared experiments where the water, brought from the cemeteries, had been filtered and deprived of all visible food material and then provided with large numbers of egg-rafts, enormous numbers of young larvæ were produced, their growth being prodigious, and many of the younger larvæ were devoured. The large numbers of larvæ sacrificed in this way seemed out of all proportion to the numbers surviving. Surviving larvæ fed under these conditions develop rapidly, and instances are on record of pupation taking place soon after the sixth day in consequence, conditions of temperature and humidity, of course, being exceptionally favourable.

CEMETERIES AND *C. FATIGANS.*

During a survey of the following three cemeteries made in mid-summer 1927-28, the hereunder mentioned conditions were found to exist:—

Nudgee Cemetery.

Graves Examined.	Total Number of Vessels.	Vessels with Water.	Vessels found breeding.	Percentage of Graves breeding.	Percentage with Dead Larvæ.	Types of Mosquitoes found.	pH Range.
127	420	340	96	75·5	40·2	*C. fatigans* 84·4% *A. notoscriptus* 2·3% *A. annulipes* 0·9% Associations of *C. fatigans* and *A. notoscriptus* 12·4%	6·6–8·6

This cemetery, though situated in the Greater Brisbane area, is right outside the city proper in an eight-mile radius, and is, therefore, subject to sylvan conditions, and on account of its comparative isolation is not breeding the essentially domestic *A. argenteus.*

The enormous number of egg-rafts laid in jardinière of a half-gallon capacity was very noticeable; various lots of 50, 25, 18, and so forth laid in one vessel were quite common. Such jardinières are great favourites and are especially selected; of 71 taken on these graves alone, 44 were found breeding *C. fatigans.*

Nundah Cemetery.

Graves Examined.	Total Number of Vessels.	Vessels with Water.	Vessels found breeding.	Percentage of Graves breeding.	Percentage with Dead Larvæ.	Types of Mosquitoes found.	pH Range.
150	493	430	94	62·6	30·4	*C. fatigans* 97·4% *A. argenteus* 0·7% Associations of *C. argenteus* and *C. fatigans* 1·9%	7·4–8·0

Nundah Cemetery, previously known as German Station, is situated in the four-mile radius. It is isolated on high ground surrounded on three sides by hyacinth-covered swamps, doubtless partially polluted from the cemetery itself. This explains to some extent the absence of associations of *A. notoscriptus,* &c., and the presence of *C. fatigans* as the dominant mosquito; the few examples of *A. argenteus* could be definitely traced to graves in close proximity to the caretaker's lodge. The largest number of vessels on any one grave numbered 28; 65 per cent. of these were breeding *C. fatigans;* two large jardinières were included in this lot; one more exposed than the other had 45 egg-rafts in addition to numbers of larvæ, &c., in all stages, and the other jardinière exposed to the full heat of the sun contained putrid water and hundreds of dead larvæ, and especially large numbers of dead pupæ.

Lutwyche Cemetery.

Graves Examined.	Total Number of Vessels.	Vessels with Water.	Vessels found breeding.	Percentage of Graves breeding.	Percentage with Dead Larvæ.	Type of Mosquitoes found.	pH Range.
100	404	310	67	67	13·0	*C. fatigans*	6·6–7·8

Lutwyche Cemetery is on the main Gympie road in the four-mile radius. No mosquitoes other than *C. fatigans* were taken here. The proximity of this cemetery to four tanneries with the subsequent pollution of natural watercourses, and the flooding of the whole neighbourhood with *C. fatigans* in consequence (prior to the existence of mosquito work in this area) may be advanced as a possible explanation.

TECHNIQUE EMPLOYED.

It may be advisable to add a few lines with regard to the technique employed in the identification of larvæ bred in cemetery jars. When jars are fully supplied with larvæ it is naturally somewhat difficult to *avoid* missing one here and there, and, in order to make it possible to keep all under observation, a method of pouring the contents of the jar into a 1,000 c.c. measuring glass and filling up the same with water was used; by this means the water becomes more transparent and the larvæ are made to pass to and fro under observation, whilst a long pipette introduced will bring any coveted specimen to the surface for further examination. If the water is very dark and muddy, as frequently happens, no larvæ may be visible, and in such a case it will be necessary to decant only small quantities of the fluid at a time; but with patience accurate results can be obtained.

C. FATIGANS AS A TREE-CAVITY BREEDER.

Although *C. fatigans* is found breeding in tree cavities here and there, it is evidently not a tree-breeding species, nor does it occur in sufficient quantities in trees to make it a serious menace in mosquito control. Associated with *C. fatigans* in such cavities in midsummer we find larvæ of Syrphid flies, Chironomids, and Culcicoides sp., &c., the pH of such water being usually in the region of 6.0-6.5.

C. FATIGANS UNDER LABORATORY CONDITIONS.

In the laboratory, *C. fatigans* will oviposit at some time or other on any available water. During the course of the last eighteen months, various jars containing Charophyta have been under constant observation; the following species were used, being easily procurable:—

(1) *Nitella diffusa* Braun;
(2) *Nitella cristata* Braun;
(3) *Nitella myriotricha* Kütz;
(4) *Nitella phauloteles* Groves.

These yielded a constant supply of egg-rafts available for experimental work as desired. (See Hamlyn-Harris, 9.)

OBSERVATIONS: EGGS LAID IN JARS CONTAINING THE AQUATIC PLANT, NITELLA SP.*

Observation No. 1—

Egg-Raft Laid.	Number of Larvæ Produced.	Total Number Matured.	Number of Females.	Number of Males.	Final Emergence.
30–9–26 (Spring) ..	259	128	82	46	29–11–26

Observation No. 2—

Egg-Raft Laid.	Number of Larvæ Produced.	Total Number Matured.	Number of Females.	Number of Males.	Final Emergence.
10–5–26 (Autumn) .. Hatched on 11–5–26	256	170; 3 larvæ, 8 pupæ died, leaving a total of 75 unaccounted for	84	86	28–6–26

In *Observation No. 1* a total loss of 131 larvæ was registered, spread over a period of two months. Of the remaining 128, 34 males and 37 females matured during the first month (September). The only food supplied in this instance consisted of dried blood given as required.

In *Observation No. 2*, during the whole of the seven weeks the water remained unchanged but was added to when necessary, the pH remaining in the region of 8.6. Agar was used as food supplemented by blood preserved in 1/560 formalin. During the whole period the temperature ranged from 64 to 73 deg. F.

Rates of development of larvæ during midwinter—

		Temperature. Deg. F.
Raft of 256 eggs laid	May 10 ..	73
Eggs hatched out	May 11 ..	72
Appearance of 1st pupa	May 24 ..	67
Emergence of 3 imagos, *all males* ..	May 27 ..	67
Emergence of 3 imagos, 9 males ..	May 28 ..	65

*There seems no reason to differentiate between the various species since they all without exception behave similarly, though *A. argenteus* is more persistent in selecting them than is *C. fatigans*.

			Temperature. Deg. F.
Emergence of 3 imagos, 6 males ..	May 29	..	65
Emergence of 1st female	May 29	..	65
Emergence of 17 males and 6 females	May 31		

Making a total of 35 males as against 7 females, 42 in all, during the first three weeks.

The preponderance of males over females continued until about the 20th June, after which date only females emerged. The temperature was taken at 9.30 a.m. each day, and during this period never registered less than 65 and not more than 68 deg. F. Whilst being fed on Agar all larvæ were of an opaque whiteness, which, however, vanished when fed on blood. There was a period of exceptionally slow growth about the 9th June, when for seven days no males but only five females matured, and what appeared to be a kind of intoxication seemed to have set in, a state of things rectified, however, by the addition of fresh Agar and blood.

Observation No. 3.—Six individual egg-rafts taken at random yielded the following results:—

Egg-Raft Laid.	Number of Larvæ Hatched.	Number of Pupæ Matured.	Percentage Maturing.
1. 28- 9-26..	75	No record	..
2. 28- 9-26..	259	140	54·05
3. 28- 9-26..	227	No record	..
4. 31-10-26..	158	19	12·00
5. 15-11-27..	328	241	73·40
6. 5-12-27..	295	193	65·40

Unfertile Eggs.—In addition to the above records there is evidence that some egg-rafts are laid which fail to produce larvæ. It is impossible at this stage to give any reason for this, but the idea that mosquitoes can lay unfertile eggs has now become a firm conviction, and further research is highly desirable. Dr. W. Rudolfs, of New Jersey, has confirmed this, and in a letter to the author makes the following statement:—

> "Last summer we were feeding larvæ of the house mosquito more or less pure cultures of Protozoa and Algæ. During this study of food requirements, our Zoologist noted that in a number of instances mosquitoes which hatched from these larvæ laid unfertile eggs. We have no conception at present what the cause is, but since it was noticed several times we made a record of it and are planning to follow it up some time in the near future."

Further evidence as to the non-fertility of eggs is produced by Brug (2).

SEPTIC TANKS.

It is here necessary to draw attention to septic tanks being actual and potential breeding places of *C. fatigans*. It has been known for a long time that under favourable conditions such tanks may afford ideal breeding places. Our records point to about 50 per cent. of the tanks installed in this area breeding, and owing to this it has become imperative to insist on the screening of every pipe connected with the exterior of the tank as a means of permanent control. This condition is brought about either by the breaking of the "scum" or by the presence of a second chamber in which a "scum" is not formed. Septic tanks are sometimes selected during the process of construction, and, when sealed with larvæ in full possession, do not apparently produce a "scum" and in consequence become a special menace in mosquito control. This type of breeding place obviously must be taken into account in any mosquito control measures adopted in centres of population.

C. FATIGANS IN HUMAN FÆCES.

Human fæces, although providing adequate food material for the larvæ of this species, is as a rule too crude a material for such breeding places to become selective. Several instances of *C. fatigans* breeding in such material have been observed at seaside resorts in the contents of sanitary pans, diluted by rain, left standing out of doors.

C. FATIGANS IN RELATION TO TANNERIES.

Watercourses polluted by tanneries are favourable breeding places of *C. fatigans*. When the waste is first released, it is extremely acid and mosquitoes will not breed in it, but gradually as the dark coffee-coloured liquid gets further away and becomes alkaline it is extremely attractive to *C. fatigans*, but no associations occur until the pollution becomes considerably less pronounced, when *A. annulipes* and *C. annulirostris* are found in association. Surveys of tanneries reveal numerous breeding places, and it is unnecessary in a paper of this nature to enumerate all of them, but one or two are here referred to as demanding special vigilance.

(1) *Soak-water*.—It is in this water that the hides are washed before going into the lime liquors, and if allowed to remain standing after the hides have passed through it becomes an important breeding place. If, however, such pits are kept regularly under observation, they can be made to act as *excellent lures*, and many larvæ can be eliminated by such means.

(2) *De-liming solution containing boracic acid*.—The strength of this solution is usually about 0·5 per cent. After use the boracic acid is changed to calcium borate by the lime in the hides. These solutions, if allowed to stand, are not in any way repulsive to *C. fatigans*.

(3) *Lime Pits*.—Lime pits in actual practice are capable of breeding millions of mosquitoes. It was Borel (1) who said that a coating of white lime prevents the deposition of mosquito eggs in water containers.

Our experience is that, in a saturated solution containing 0·132 grams of lime per litre at 15 deg. C., mosquitoes will not lay their eggs as long as $CaCo_3$, by the absorption of Co_2 from the atmosphere, forms a solid and insoluble film on its surface. As the solution becomes weaker, owing to the film being broken by wind or other causes, *C. fatigans* is given the opportunity it requires, and breeding is apt to go on rapidly. Unused lime pits are therefore a serious menace, and demand constant control.

(4) *Tan Liquor Pits.*—The pH of the liquor in the pits (due to lactic and acetic acids) varies between 3.3-4.5, according to the tanning material used. As long as this hydrogen ion concentration is maintained *no* mosquitoes will lay their eggs on it. The pH of the weaker liquors in use is somewhere in the region of 5.2-5.8, but even this is not selected. What the real significance of the film of yeast which forms on the surface of tan liquors may be, and whether it has any deterrent effects in itself apart from the acidity of the liquor, is difficult to determine. All tanning matter in solution tends to decompose or become precipitated. Decomposition is greatest at the surface, on account of the greater warmth and the presence of oxygen. If left standing long enough, the surface of such liquor will become so watery that *C. fatigans* will select it unremittently. Breeding may be controlled by covering the surface with a heavy layer of a volatile oil such as kerosene, with the following results:—(1) Arrest of decomposition, (2) prevention of mosquito-breeding, (3) no injury to tanning liquor.

SUMMARY AND CONCLUSIONS.

1. *C. fatigans* is found associated with no less than nine different species of mosquitoes in the Greater Brisbane area. The association is dependent, to a very large extent, upon the state of the water at the time of selection.

2. There exist cyclic variations in the associations referred to, due to rain and atmospheric conditions in which temperature and humidity play no small part. These cyclic alternations must not be regarded as incapable of variation, but rather as a sign of interesting possibilities.

3. The study of hydrogen ion concentration, within certain limits, of waters selected for breeding purposes, does not throw any light upon the reason for selection, but only serves as an indication of the type of water preferred by certain kinds of foodstuffs or organisms, or aquatic vegetation, as the case may be.

4. There is considerable mortality among the developmental stages of *C. fatigans* at all times, but especially during hot summer weather. It is surmised that this is due either to a species of intoxication or narcotic poisoning, or to the toxic nature of the decomposition products, especially induced by a high temperature.

5. Investigations into the breeding of mosquitoes in the Brisbane cemeteries lead to the belief that *C. fatigans* and *Aedes notoscriptus* choose the artificial receptacles on graves more so than other mosquitoes,

and use them to the full extent of their power. *C. fatigans* holds undivided sway in some cemeteries, *Aedes argenteus* choosing vessels near human habitations for preference.

6. *C. fatigans* is not by nature a tree-cavity breeder, but might become so as elective breeding places become scarce.

7. *Mucidus alternans,* a cannibalistic species, and *Aedes* (*O.*) *vigilax,* usually associated with it, are both by nature saltwater marsh mosquitoes, but their presence at certain times of the year in large numbers in fresh waterholes is significant and highly undesirable. When these occur in association with *Aedes vittiger* it is interesting to note that, in spite of the fact that the larvæ of *Aedes vittiger* are predaceous, they will, nevertheless, avoid any intercourse with the other two mosquitoes even if found in the same water, and will select a secluded spot where they are less liable to attack. It is surmised that *Mucidus alternans* and *Aedes vigilax* select *fresh* water only from compulsion.

8. Further observations show that the Charophyta referred to in this article and comparatively common around Brisbane do not thrive in *pollution,* and hence, when mosquito larvæ exist in conjunction with *Nitella* in the field, it is usually in the company of *A. annulipes* and with other sylvan mosquitoes rather than with *C. fatigans.*

9. Under laboratory conditions, however, it is quite a common thing for *C. fatigans* to lay egg-rafts upon *Nitella* water, though *A. argenteus* selectively seems to do so more frequently.

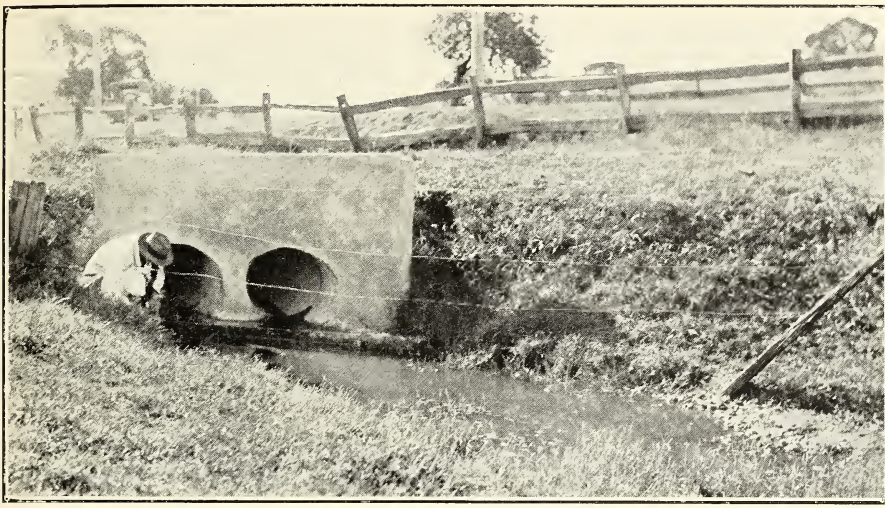
10. As is to be expected, the size of the egg-rafts of *C. fatigans* is entirely dependent upon the state of maturity of the female responsible for them. Experiments go to show that males mature first. It would appear that the presence of food is not the main determining factor in the rate of development. It is surmised that the nature of the water itself, in its ability to preserve food supplies in a perfect state without any adverse decomposition products, is of more importance than has been thought likely; other determining factors such as temperature, humidity, &c., being only contributory. In experimentations in the field, as well as under laboratory conditions, it was found that the vitality of larvæ was in direct proportion to the concentration of decomposition products of the water contents.

11. Though the presence of food, therefore, seems to be the determining factor in the selection of its breeding places, the number and quality of the decomposition products in the water may be said to be the main determining factors with regard to the measure of retardation in development of *C. fatigans.*

12. Under laboratory conditions eggs sometimes fail to produce larvæ, and it is therefore naturally surmised that unfertile females, even though possibly fed on blood, produce unfertile eggs.

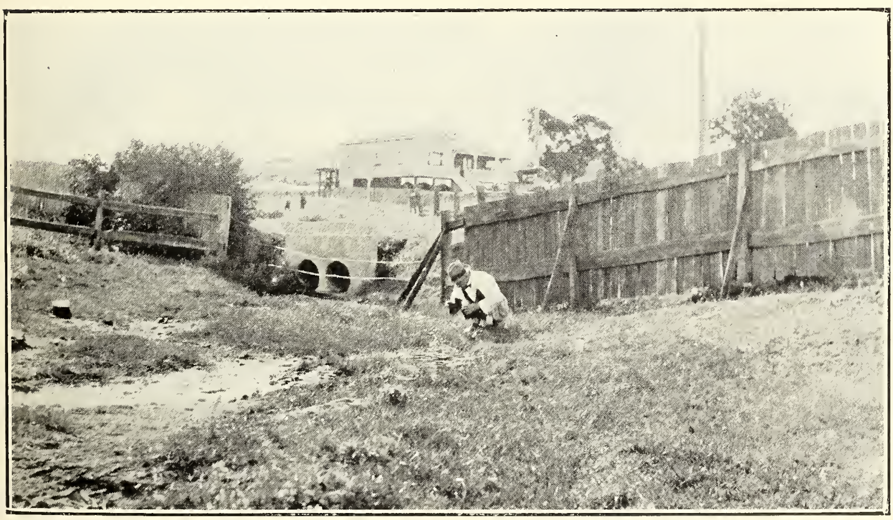
13. The possibilities of the septic tank as a breeding ground for *C. fatigans* must be recognised in any active anti-mosquito campaign,

CYCLIC ALTERNATIONS.



Culvert over Natural Watercourse (Brisbane).

Fig. 1.—Breeding-place of *Aedes* (*O.*) *vittiger* in February 1927. A month later *Lutzia halifaxi* reigned supreme here. With the advent of winter this species was displaced by *C. fatigans*.



Natural Storm-water Channel (Brisbane).

Fig. 2.—Breeding-ground of *C. annulirostris* and *Anopheles annulipes* in association; both these mosquitoes will breed here most of the year round when pollution is of the slightest and the watercourse does not dry up. *C. fatigans* breeds here with increased pollution.

CYCLIC ALTERNATIONS.

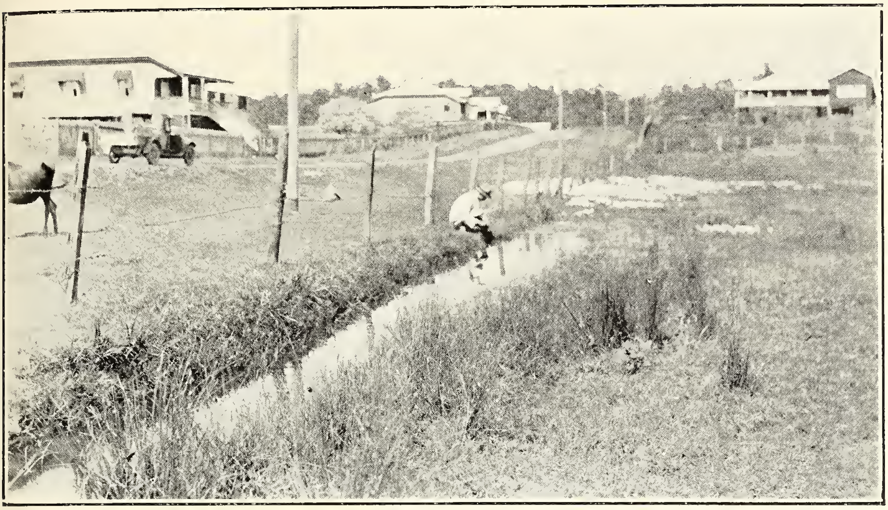


Fig. 3.—Breeding-ground of *C. annulirostris* and *A. (F.) alboannulatus* in association, during the winter of 1926, in company with *Nitella diffusa* when the pH stood at 6.8 after a long period of rainy weather. A year later pollution became more and more apparent, *Nitella diffusa* disappeared, and *C. fatigans* displaced the other two mosquitoes (pH 6.4). (St. Lucia, Brisbane area.)

Fig. 4.—Typical fresh-water breeding place of *A. (O.) vittiger* at the entrance to the Brisbane River sometimes submerged by very high tides. *Mucidus alternans* and *A (O.) vigilax* were found here in association with the above in large numbers. (Lytton, Brisbane area.)

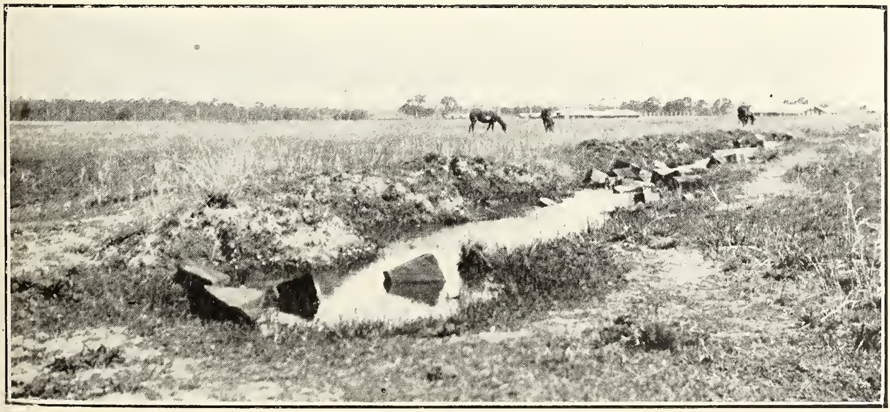


Fig. 5.—An old trench 2 feet deep making a typical breeding-place for several "pest" mosquitoes of the "Vittiger" type, but not selected by *C. fatigans;* though this mosquito breeds freely in the tins which float on its surface, *C. fatigans* avoids the water itself (pH 6.4). (Lytton, Brisbane area.)

and the screening of the pipes connected with the exterior made an imperative necessity.

14. Brisbane possesses a number of tanneries which, in the ordinary course of events, produce pollution responsible for enormous numbers of *C. fatigans.*

15. Soak-water, de-liming solutions, and lime-pits are also capable of breeding prodigious numbers, though in the latter a film of $CaCo_3$ will, so long as it subsists, debar mosquitoes from breeding in them.

16. Tan liquor pits are far too acid for selection, but, as the liquor weakens and decomposition of the surface proceeds, *C. fatigans* may select it preferentially.

LITERATURE CONSULTED.

1. Borel, M.—Au sujet de l'action empechante de la couleur blanche sur la ponte des moustiques, dans les jarres indigenes blanchies a la chaux. Bull. Soc. Path. Exot. 1926, v. 19, 702.

2. Brug, S. L.—Remarks to the previous paper of Professor Dr. W. H. Hoffman. Mededeelingen van den Dienst der Volksgezondheid in Ned-Indie., vol. 17, pt. 1, 1928.

3. Buxton, P. A., and Hopkins, G. H. E.—Race Suicide in *Stegomyia.* Bull. Ent. Res., xvi., pt. 2, Oct. 1925.

4. Buxton, P. A., and Hopkins, G. H. E.— Researches in Polynesia and Melanesia, pts. i. to iv., No. 1, Memoir Series, London School of Hygiene and Trop. Med., July 1927.

5. Carter, H. R.—Preferential and compulsory breeding-places of *Aedes* (*Stegomyia*) *œgypti* and their limits, Ann. of Trop. Med. and Parasit., xviii., No. 4, Dec. 1924.

6. Dunn, L. H.—Further observations on Mosquito-breeding in tree-holes and crab-holes. Bull. Ent. Res., vol. 18, pt. 3, 9th Feb., 1928.

7. Hacker, H. P.—Federated Malay States Malaria Bureau Reports, vol. 11, Nov. 1920, pp. 12-24.

8. Hamlyn-Harris, R.—Notes on the breeding-places of two Mosquitoes in Queensland. Bull. Ent. Res., vol. xvii., pt. 4, June 1927.

9. Hamlyn-Harris, R.—The relation of certain Algæ to breeding-places of Mosquitoes in Queensland. Bull. Ent. Res., vol. xviii., pt. 4, May 1928.

10. Moroshita, K.—Experimental observations on the habits of *Cu'ex quinquefasciatus* Say, with special reference to the influence of Hydrogen ion Concentration. Journ. Med. Ass. Formosa, 1925, Summary Rev. App. Ent. B., vol. 14, p. 114.

11. Williamson, K. B.—Mosquito-breeding and malaria in relation to the Nitrogen Cycle. Bull. Ent. Res., vol. xviii., pt. 4, May 1928.

Stress Transmission in Frictional-Cohesive Material.

BY R. W. H. HAWKEN, B.A., M.E.

(*Read before the Royal Society of Queensland, 24th September, 1928.*)

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SUMMARY.

This is an inquiry into the question of stress transmission in material other than fluids. Fluid pressure is taken as the fundamental law, and the change in stress throughout the material, arising from potential frictional and cohesive resistance to shear, separately and conjointly, are expounded.

The author's method goes on the assumption that the cohesive resistance is independent of previously existing stress equilibrium for non-cohesive material. Consequently, in the computation, cohesion is treated as an independent shear introduced as a maximum on a plane with corresponding shears on all other planes. The plane on which the shear " *c* " is introduced will be the " Critical Plane of Equilibrium.'

In the ellipse of stress deduced, the active shear on the critical plane is equilibrated by the potential resistance to shear due to both frictional and cohesive resistance.

The outstanding factor of the analysis here set out is that the principal planes for frictional-cohesive material differ necessarily in direction from those for the same loading, presuming no cohesion.

In the author's view, the theories of Rankine ("Earth Pressure"), of Navier ("Failure in Compression"), and Guest, as to Failure by Shear, are special limiting cases. Those of Scheffler ("Unsupported Banks"), Ketchum ("Trench Cutting"), Bell ("Pressure in Clay"), and any "Straight Line Wedge" theory for "Cohesive Material," have the same basic error, namely, that a limiting condition, impossible practically, is assumed as existing for the general case.

The author's view being at variance with accepted theories, the reasons are discussed from several aspects and illustrated by examples, theoretic and practical.

INTRODUCTION.

Consequent to his investigations of the theory of the pressure of non-fluid material, such as sand or soil, on a supporting wall, the author came to the conclusion that, for the purpose of computing stress transmission, any material may be regarded primarily as a fluid.

Dry sand has frictional resistance to shear. Soils have some tensile strength or cohesion in addition to frictional resistance: and finally, "solids" in which cohesion predominates may, or may not, have frictional resistance.

The behaviour of such materials can be deduced from the influences of friction and cohesion, separately and conjointly, on a supposititious fluid of the same dimensions and loading.

The subject is fundamental to any treatment of the strength of materials, and has attracted the attention* of mathematicians and physicists as well as engineers.

The many authorities differ in regard to assumptions, and more still as to conclusions. At the risk of repetition, an attempt will be made to correlate and amend existing theories in the light of the author's generalisation of the problem.

DEFINITIONS AND NOTATION.

Frictional Resistance is potential resistance to movement in the direction at right angles to, and due to, applied normal stress.

[*Note*: The law assumed is that tangential resistance varies directly as the normal stress, but the general reasoning would not be affected if the resistance were assumed to vary as some power of the normal.]

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* See "History of the Development of Lateral Earth Pressure Theory," by Dr. Jacob Feld, Proc. Brooklyn Engineers' Club, July 1928, pp. 61-104. This able review does not discuss the important investigation of A. L. Bell expounded in the present paper.

Cohesive Resistance is potential resistance to movement independent of the normal stress.

[*Note* : Cohesive Resistance as defined implies equal resistance to tension and compression, but this resistance to tension and compression is not the "Tensile Strength" nor "Compressive Strength" as usually understood, for reasons to be explained.]

Principal Planes are two planes at right angles to each other on which pure normal stresses exist, that is, on which there is no shear.

The Critical Plane of Equilibrium ("*Critical Plane*") is the plane on which incipient movement would take place. It may become also "The Plane of Rupture."

[*Note* : All planes are infinitesimal, that is to say, lengths are considered small enough to justify the assumption of uniformity of conditions over the length.]

The Notation used is as follows :—

c is the value of cohesion presumed constant, that is, resistance to movement $= n' \tan \phi + c$;

n is normal stress on a plane ;

s is shear stress on the same plane as "n" exists ;

β is the varying angle added to the angle of friction by cohesion giving a "virtual" angle of friction $(\phi + \beta)$;

γ is the complement of $\phi = \pi/_2 - \phi$;

θ is the angle made by any plane with the principal plane ;

ϕ is the angle of friction, that is, frictional resistance to movement $= n \tan \phi$;

ρ is the angle made by the Critical Plane with the Principal Plane.

A suffix "$_0$" *is attached* when cohesion is not acting, that is for frictional non-cohesive material. *A dash is added* when cohesion is acting as well as friction, that is, in frictional-cohesive material. *A suffix* "$_1$" is added for cohesive non-frictional material.

Thus p_0, q_0 are principal stresses presuming no cohesion, and p', q' are principal stresses presuming cohesion and friction. n' is the normal in an ellipse (p', q'). Similarly with other symbols.

FLUIDS, FRICTION, SHEAR, AND COHESION.

A short review of general principles, as interpreted or developed by the author, will be given as follows :—

Fluid.

The primary experimental law of static equilibrium is "fluid pressure," that is, that any pressure applied in any direction transmits, or has equilibrating stresses, in every direction, of the same intensity..........(1)
That is to say, the "ellipse of stress" is a circle and the principal planes are indeterminate,* or, in other words, all planes are principal planes....(2)

* Actually the direction of the applied load if purely normal (c.f. gravity) is one principal stress, and, on any other planes, the stress is infinitesimally less.

Friction and Shear.

The next step is to assume the material to have frictional resistance to shear. Then the equilibrating principal stress is the least possible to preserve equilibrium.

For the limiting conditions of equilibrium on a certain plane (called the "Critical Plane of Equilibrium"* by the author), the principal axis makes a known angle with the Critical Plane........................(3)

In symbols—

If ϕ is the angle of friction $= \pi/_2 - \gamma$, then the principal axis makes an angle $\pi/_4 - \phi/_2$ or $\gamma/_2$ with the critical plane....................(4)

This relation has been deduced† from a consideration of the limiting relation between shear or tangential stress "s," and the passive resistance to shear $n \tan \phi$, due to normal stress "n," namely—

that $s = n \tan \phi$ on the critical plane......................(5)

Also, as such plane is unique—

if θ is the angle made by a plane with the principal plane,

$$\frac{ds}{d\theta} = \frac{d}{d\theta}(n \tan \phi) \quad \text{.................................(6)}$$

Or, graphically—

The curve of $n \tan \phi$ touches the curve of "s" for the value of θ, deduced from (5) and (6) and given by (4)........................(7)

So far as frictional resistance alone is concerned, the state of affairs is—

If the direction of the critical plane is known or fixed, then the direction of the principal stress is also known, that is, is given by (4) ....(8)

Or conversely—

If the direction of the principal stress is known, then the direction of the critical plane is known...(9)

In symbols and quantitatively—

If p_0 and q_0 are the principal stresses for non-cohesive material, and if ρ_0 is the angle between the critical plane and principal plane, it has been shown that—

$$q_0 = p_0 \tan^2 \gamma/_2 \quad \text{............(i)}$$

$$\text{and } \rho_0 = \gamma/_2 \quad \text{..................(ii)}$$

also on the critical plane the resultant intensity makes an angle ϕ with the normal, and the vector components of the resultant are at right angles to each other ....(iii) ....(10)

---

* The term "Plane of Rupture" is inappropriate when speaking of conditions of equilibrium. It might be called "The Plane of Incipient Rupture."

† The original deduction by Rankine follows different lines, see (10) below, which summarises Rankine's method.

In words, (10) may be expressed as follows :—

In a frictional material (presumed non-cohesive), a principal stress "p_0" on one plane transmits, or is equilibrated by, a stress "q_0" on the plane normal to the first, and stresses in other directions according to the ellipse of stress ; and the Critical Plane, or plane on which the limiting conditions of equilibrium exist, that is, on which incipient failure occurs, makes an angle $\gamma/_2$ with the direction of the Principal Plane............(11)

Cohesion.

In general terms :—

A normal stress on one plane must be accompanied by a concomitant reaction on the plane at right angles to that in which the load is applied. In non-cohesive material such reaction is positive. In frictional-cohesive material, for the cohesive resistance to be fully developed, it may be positive, zero, or negative, according to the cohesion functioning........(12)

THE ELLIPSE OF STRESS.

Any condition of statical stress equilibrium, however complicated apparently, actually consists of—

(*a*) Normal stresses of equal intensity, F say, and the same sign on two planes at right angles ;
together with—

(*b*) Normal stresses of equal intensity, S say, and of opposite sign on the same two planes..............................(13)

The Planes mentioned in (13) are the Principal Planes ; on any other plane the resultant stress is the vector addition of F normal and S inclined at an angle 2θ with the normal. The resultants are the polar co-ordinates of the ellipse of stress*......................................(13A)

That is—

(*a*) Fluid Pressure F in all directions ;

(*b*) Normal Stress of equal intensity S, of opposite signs on two planes of definite direction, that is, shear of the same intensity S on two planes making angles of 45° with the definite direction mentioned.........................(14)

That is—

(*a*) Fluid Pressure F ;

(*b*) Shear S on a plane in a definite direction.................(15)

Result (15) shows that the *direction* of the principal planes is determined by the direction of, and amount of, shear. The normal fluid stresses have no influence on the *direction* of principal planes ; they contribute to intensities only on such principal planes, as they do to the normal intensities on all planes..(16)

Again, from (13) and the Ellipse of Stress—

$$F + S = \text{one principal stress, } p$$
$$F - S = \text{other principal stress, } q \quad \ldots\ldots\ldots\ldots(17)$$

---

* A detailed exposition is given in "Critical Planes," Trans. I. E., Aust., 1928.

The effect of cohesion has been examined in the author's paper "Critical Planes in Cohesive Material"* from the point of view of finding the position of the principal planes for frictional-cohesive material, relative to the principal planes for no-cohesion.

The standard analyses assume the principal plane to be the same in both cases, but the author maintains that this assumption is wrong, and will endeavour in what follows to expound his views.

FRICTIONAL NON-COHESIVE MATERIAL.

Rankine Theory.

As in a fluid, the material must be supported laterally at any depth and at every depth, also, q_0 is always less than p_0 and approaches zero for non-cohesive material when $\gamma/_2$ approaches 0, that is, $\phi = 90°$.

A non-cohesive material has some "angle of friction" intermediate between the limits $\phi = o$ and $\phi = 90°$.

The theoretic deduction obviously is for a regular material, and the ϕ assumed and consequential slope of the critical curve, is for so much of the material over which conditions may be reasonably assumed constant† ....(18)

Under self-loading conditions, the extraneous stress is gravity acting vertically, consequently, for gravity as the load, the principal stress may be assumed vertical,‡ the other corresponding principal stress is horizontal, that is, normal to the applied stress...................................(19)
This conclusion is, apparently, not borne out by experiments which record an inclined stress on the vertical wall. No method has as yet been applied extensively to measure§ static pressure in the form suited to check the deductions experimentally. For this purpose, a series of "pressure gauges" to record vertical, horizontal, or inclined intensities, each over a small area at various points, would be required.

To the author it seems that next the wall, say in a bin, movement attempts to take place along the face due to the straining or horizontal

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* Proc. Inst. of Engineers, Aust., 1928.

† Various portions or various grains of irregular shape may cause secondary bends or irregularities on a smooth critical curve, or line.

‡ The surface is not necessarily level. The effect of a sloping or irregular surface is considered by the author to cause the line joining points of equal principal stress to be parallel to the surface.

§ The difficulties of measuring pressures in certain materials may be realised when it is remembered that a gauge inside a solid might record zero pressure, as the line of pressure goes round the space; similarly in any cohesive material any gauge-testing results would need to be interpreted. The possibilities of Dr. Goldberg's pressure measuring apparatus seem attractive; also those of the Main Roads Research Dept., U.S.A., and of Prof. Bridgman's method of utilising the electrical resistance of a metal according to pressure.

movement of the wall, consequently, at the face of the wall, the ellipse may be inclined owing to the plane of incipient movement* (the Critical Plane) being vertical....................................(20)

Wedge Theory.

These theories presume a triangular wedge at the back of a wall of such dimensions that the pressure on the wall is a maximum. For the case of level filling of non-cohesive material, the resulting pressure is the same as that got by the Ellipse. If the author's views, as expounded later for cohesive material, are correct, such triangular wedges are, at best, approximations† to areas with a curved boundary since they presume a constant inclination of the critical plane to the vertical...................................(21)

COHESIVE NON-FRICTIONAL MATERIAL.

If a shear is introduced on any plane not at 45° with the principal axes, a new ellipse must exist whose axes are necessarily inclined to that previously existing ....(22)

The theorem stated in (22) may be illustrated by the following example, in which the results obtained are the same as those arrived at by the usual analysis‡ of the case quoted.

A Bolt in a Bracket.

To find the ellipse of stress :—

A direct stress " t " exists on one plane and a shear " c," independent of " t," exists on the same plane (with a concomitant shear " c " on the plane at right angles).

Referring to Figs. 1, 2, 3

Let t be external direct normal stress on AB.

Let c be external shear on AB independent of " t."

This is really the case of an inclined stress on one plane. (Fig. 1)...(23)

These conditions are equivalent to—

(1) (a) Direct Stress $t = (t/_2 + t/_2)$ on AB and
$(t/_2 - t/_2)$ on YZ (Fig. 2)......(i)
$= t/_2$ fluid pressure..............(ii)
together with—
$t/_2$ shear on OM, OM' at 45° with OB and....(iii)

(2) "c" on OB (Fig. 3)..........................(iv)

---

* Dr. Jacob Feld used a vertical door pressing on weigh-bridges, arranged in such a way that vertical and horizontal stresses on the vertical door could be measured. To the author it seems that a weigh-bridge depends for its action on movement, small, it is true, but movement nevertheless.

Prof. Chapman (see discussion in Trans. I. E. A., vol. 6, p. 311) has made an ingenious attempt to minimise movement.

† A cohesive material, owing to " stickiness," actually holds back a wall for a certain distance from the surface. For cohesive material, the assumption of a solid wedge acting at its centre of gravity seems to the author basically unsound in principle.

‡ See pp. 19-21, Andrews, " Theory and Design of Structures."

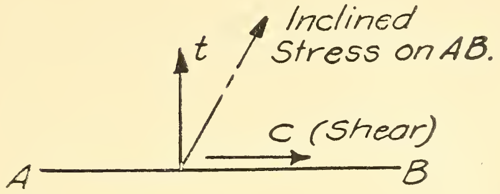


FIG. 1.

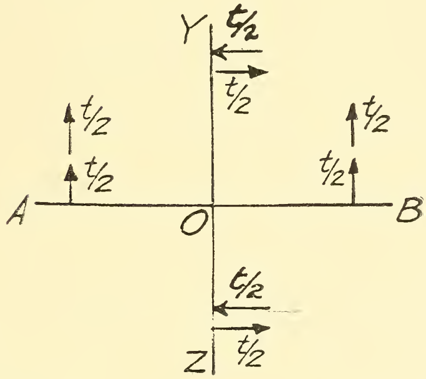


FIG. 2.

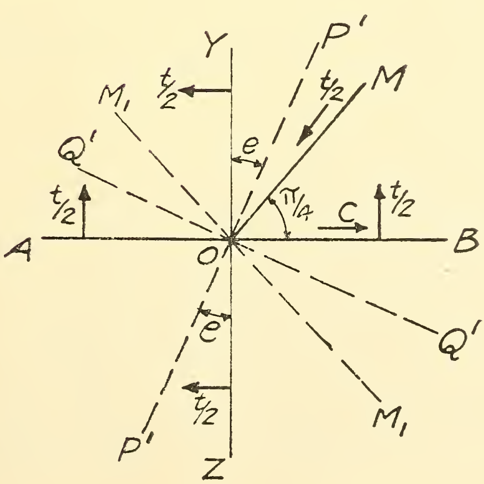


FIG. 3.

Following (13) above—

The direction of the principal stress is fixed by the direction of two shears, namely $t/_2$ on OM, " c " on OB. Principal stress is where shear = zero.* See Fig. 3.

I.e. $t/_2 \cos 2\,(45^\circ - e) = c \cos 2e$.

$\therefore \tan 2e = 2\,c/t$.......... Fig. 3 ....(24)

Conditions of Stress are—

$t/_2$ fluid pressure from (ii)—

$+\, t/_2$ inclined stress to each plane $= t/_2 \sin 2z_1$ normal, $t/_2 \cos 2z_1$ shear — on Plane making an angle z_1 with OM.

$+\, c$ inclined stress to each plane $= c \sin 2z_2$ normal, $c \cos 2z_2$ shear — on Plane making an angle z_2 with OB..(25)

For the Principal Plane—if q_a is the arithmetical value of the principal stress, which is negative

$$\text{Here } z_2 = (90^\circ - e) \qquad z_1 = 45^\circ - e.$$

$$\text{and } p_1 = t/_2\,(1 + \sec 2e)$$

$$q_a = t/_2\,(\sec 2e - 1) \ldots\ldots (26)$$

$$\text{Max. Shear} = \frac{p_1 + q_a}{2} = t/_2 \sec 2e \ldots\ldots (27)$$

These results† agree with those obtained by trigonometrical resolution.

It should be noted that the investigation given above has neglected friction resistance ; that is to say, for finding breaking stresses in terms of " c," though it applies to tensile stress approximately,‡ it will need modification if all normals have a potential resistance to shear due to friction ....(28)

It will be observed later that p', q' is the ellipse *representing internal stress at O*, found by algebraical summing of separate influences........(29)

Generalisation.

Referring to Fig. 4.

* Any number of planes each with a different shear could be reduced to a shear on one plane, implying necessarily the same shear on the concomitant plane at right angles, and thus the principal plane may be found as shown.

† *Vide* Morley, " Strength of Materials," pp. 22-23.

‡ Even for tensile stress it presumes q_0 = zero, which is not quite true if the specimen has definite size, since a ring of material forms, causing stresses on the interior portion. Poissons' Ratio in this sense may be a function of c, ϕ, and E (Young's Modulus). Again, shear intensities imply normal compressions, which again imply frictional resistance to tangential movement, the general result of which, then, is a modification as given in the Author's " Critical Planes." Actually Result (24) is a special case of the general equation—

$$\tan 2e = c/p_0 \quad \pm \operatorname{cosec} \phi).$$

See " Critical Planes" (91).

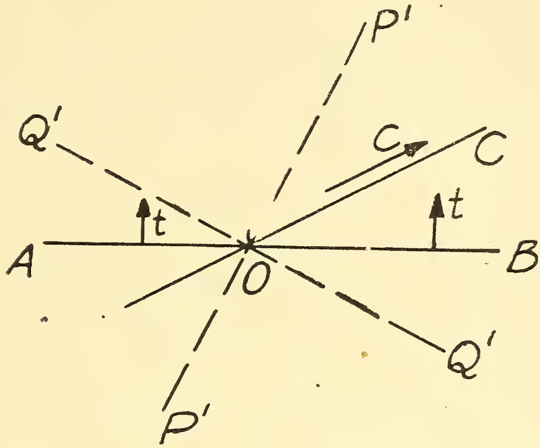


FIG. 4.

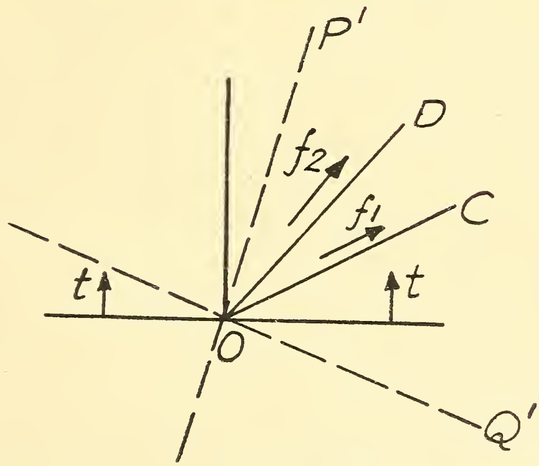


FIG. 5.

Suppose c were on a plane making an angle with OB in Fig. 4.

That is, t on OB, and c on OC, independent of each other.

OP_1, OQ_1 would have position and values corresponding to the planes on which t and c occur.

Generally see Fig. 5. If f_1 were on OC, and f_2 on OD, that is, f_3 on some other plane OE, the ellipse (p_1, q_1) finally deduced, is that for the algebraical sum of each of the separate normal and shear components, that is, stresses external to each other ....(30)

Again, (OP^1, OQ^1) would be the ellipse representing internal stresses for equilibrium at O ....(31)

Failure of Test Specimen.

A specimen usually circular or square in cross-section, whose weight is negligible relative to the applied load, is subjected to an external load causing a stress "t" on one face, and the only apparent external stresses are in the direction of the applied load and the consequential reaction. See Fig. 6.

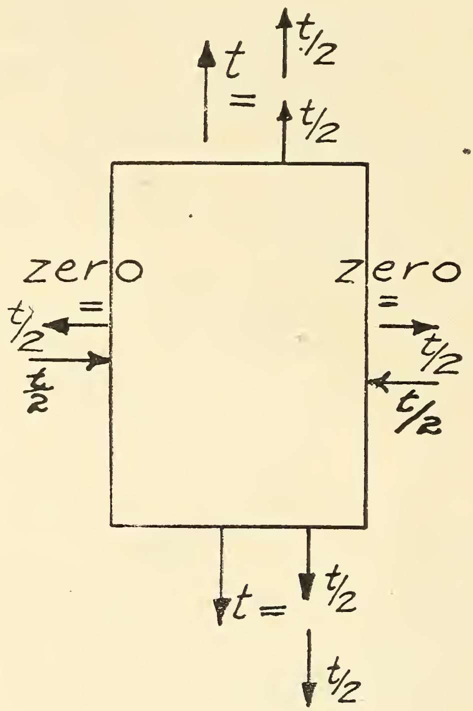


FIG. 6.

This Conventional Analysis is based on two main assumptions, namely—

(1) The applied stress is a principal stress..................(32)

(2) The concomitant principal stress is zero................(33)

Presume $+ t/_2 - t/_2$ applied on each of the faces in the direction at right angles to that of the load.

Then, regrouping stresses, it is apparent that (32) represents,

(1) A fluid stress $t/_2$ exists throughout, together with—

(2) Shear $+ t/_2$ and $-t/_2$ on two planes at right angles, that is, shear $t/_2 \sin 2\theta$ on any plane becoming $t/_2$ when $\theta = 45°$..(34)

This is the condition of stress, though apparently there is a single direct stress "t" and reaction "t" on one face........................(35)

The ellipse of stress is assumed a straight line. The error of this as a practical condition will be discussed later..............................(36)

Alternatively—

$+ t/_2$ on OQ and $- t/_2$ on OP causes shears $t/_2 \sin 2\theta$, I.e. $t/_2$ on plane at 45°.

In the specimen mentioned, it is not convenient, even if practicable, to apply tension stresses, so that an extra $t/_2$ as fluid stress causes—

$t/_2 + t/_2 = + t$ on OQ
$+ t/_2 - t/_2 =$ zero on OP........................(37)

This added fluid stress does not affect shear intensities (unless friction is taken into account), and the condition taken up is direct stress " t " on OQ, zero on OP, as assumed originally....................................(38)

Again, *Alternatively*—

" t " is applied as a pressure on one plane OQ : this would cause " t " on the plane OP at right angles if the material were fluid.

The potential shear resistance of the material is drawn on to provide shear reaction necessary and sufficient to preserve equilibrium. In the analysis this is assumed fulfilled by $q = o$............................(39)

The deductions above, by several alternative methods, have been recorded to show the concordance of several methods, but the primary assumption $q = o$* actually is misleading, since it might be taken to imply that every plane has a resultant stress in the same direction, namely OP. The slightest infinitesimal value of q would put the resultant stress on OP as horizontal instead of vertical....................................(40)

To the author the actual conditions seem to be as follows :—

In a test specimen (taken as cylindrical for clearness) and the load normal to the paper—see Fig. 7 and Fig. 8.

---

* For $q = o$ as a determinate solution in the Author's treatment (see Results (74) of " Critical Planes") of the subject, if q' and p' are the principal stresses for frictional-cohesive material, and β is the cohesion angle, that is, the angle added to the angle of friction by cohesion (it varies with the ratio of cohesion to p_0), then since—

$q' = p' \tan \gamma/_2 \tan (\gamma/_2 - \beta)$ .... (i)

Also $q' = p' \tan^2 \gamma/_2 - 2c \tan \gamma/_2$ .... (ii)

From (i)—

$q' =$ zero when $\beta = \gamma/_2$............................ (iii)

From (ii)—

$p' = 2c \cot \gamma/_2$ .... (iv)

In a Frictional Cohesive Material, for the virtual angle of friction to be 90°, then q' is negative.

In a Frictional Non-Cohesive Material, for an actual angle of friction of 90°, then q_0 is zero.

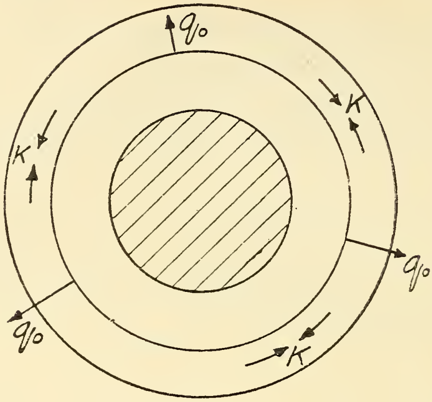


FIG. 7.

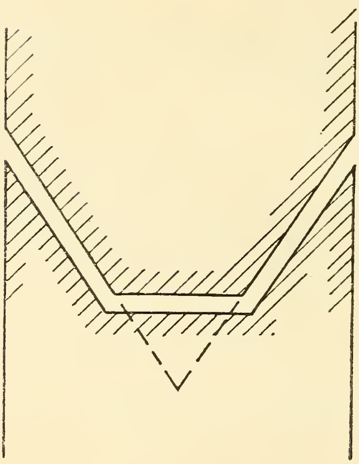


FIG. 8.

Tension Specimen so that friction phenomena do not appear directly Near the outside surface q_0 is infinitesimal, consequently, there,

$$\text{Shear} = \frac{p_0}{2} \sin 2\theta,$$

and the maximum shear on plane at 45° $= \frac{p_0}{2} \sin \pi/_2 = p/_2$........(41)

Failure will tend to take place at 45° for a gradually applied load. See Fig. 8.

Towards the interior of the specimen, q_0 has increasing possibilities, and compression ring stresses, K say, exist, as shown in the sketch. Probably K itself does not cause failure, but combined with p_0, normal to the paper, causes longitudinal shears..............................(42) This is discussed further under (69) later.

Due to ductility, such shapes occur as in Fig. 9, taken from Morley, "Strength of Materials," p. 57.

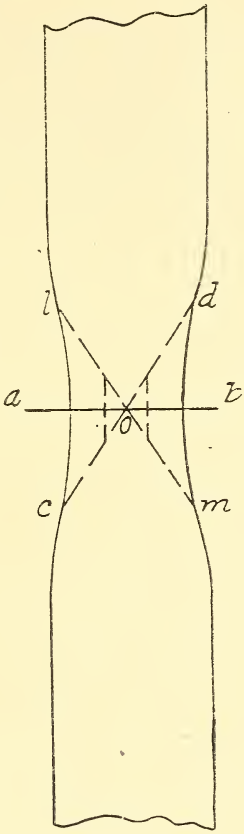


FIG. 9.

The intensity over *ab* is greater than that over *cd*, but the author cannot agree with Morley's statement—

> "The intensity of shear stress over such a surface as *cd*, Fig. 44, is not uniform, being greatest at the intersection *o*, with the plane of minimum cross-section *aob*."

Primarily the author would read "least" for "greatest" as the intensity.

$\frac{p_0 - q_0}{2}$ is least at O, but due to contraction of area, as p_0 at O is greater than p_0 at "d," the point of least shear is at some point O' near to O: but in no sense is the shear greatest near O..............................(43)

If incipient failure occurs at the outside, then the intensity p_0 when $p_0 = \frac{\text{load}}{\text{area of cross-section,}}$ increases since the load is distributed over a smaller area. But if q_0 also increases, the shear intensities (being $\frac{p_0 - q_0}{2} \sin 2\theta$) do not necessarily increase : in fact, if failure by shear is to occur, only so much shear is developed to cause failure ; perhaps from this aspect the shear intensity may be regarded as approaching constancy......(44)

Compression Specimen. Neglecting friction, the action would be similar to above with Compression written for Tension, with the modification that on the " core " M (see Fig. 10) pure compression or fluid stress will exist and no failure takes place, consequently the section failure will be as shown in Fig. 11 and 11A.................................(45)

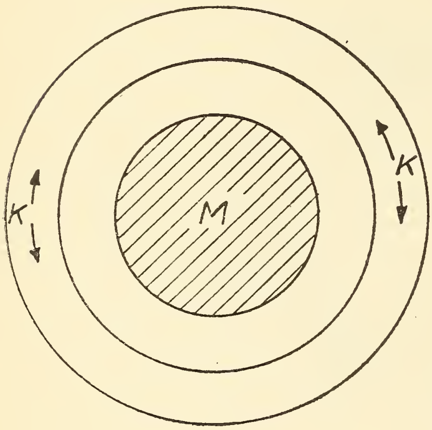


FIG. 10.

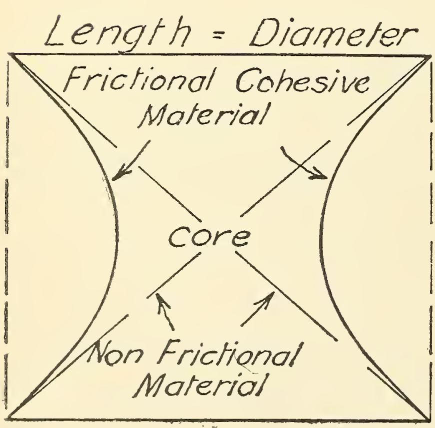


FIG. 11.

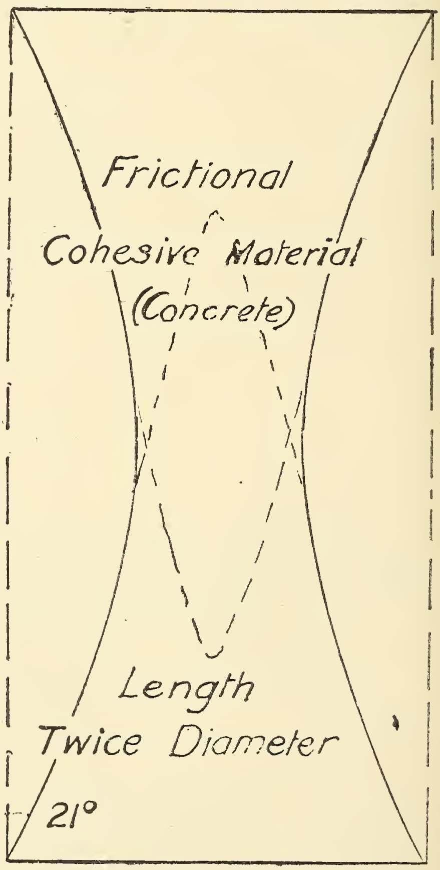


Fig 11A

The shears are $\left(\frac{p_0 - q_0}{2}\sin 2\theta\right)$ when q_0 ranges from zero at the surface to p_0 at the "core," to fit with corresponding intensities of shear. As above, maximum shears are at 45°, and, if friction does not operate, this is the plane of fracture for a gradually applied load........................(46)

Contraction, expansion, or distortion of the material affects the intensities of loading and causes variations not mentioned above, but the primary phenomena, if friction is not taken into account, appear to be as stated..(47)

Guest's Law of Maximum Stress.

The following extract from a paper,* "The Flexibility of Plain Pipes," by J. R. Finniecome, M.Eng. (Zurich), M.Soc.Ing.C. (France), has a direct bearing on the subject :—

> "The pipe designer is keenly interested in the maximum combined stress, based on the longitudinal and transverse stress, as this will determine the permissible thrust and deflection for the maximum permissible stress.
>
> The three principal theories which form the basis for determining the elastic fracture of the material are—
>
> (1) Maximum Principal Stress (Clapeyron and Rankine).
>
> (2) Maximum Principal Strain (Saint-Venant).
>
> (3) Maximum Shearing Stress (Coulomb, Guest, Mohr)....(48)
>
> For the calculation of the combined stress ths author will apply the third theory, using Guest's law, which has been confirmed by Guest's tests in 1900 for ductile materials. Guest's law is generally used in this country, and is known as the maximum stress difference theory. According to it, the maximum principal stress difference, which is equal to twice the maximum shear stress, forms the basis for the elastic fracture of the material. The maximum shear stress for two perpendicular normal stresses such as the longitudinal and transverse bending stress, is equal to half the difference of these two perpendicular stresses.
>
> We thus get the *maximum principal shear stress*—
>
> $$S_m = \frac{p - q}{2} \qquad \text{(49)}$$
>
> The maximum shear stress is in a plane inclined at 45° to the two planes of the longitudinal and transverse bending stress.
>
> In accordance with Guest's law, *the combined stress is equal to twice the maximum shear stress,* and thus we get—
>
> The combined stress $= (p - q)$......................(50)

* "Metropolitan-Vickers Gazette," May 1928, p. 400. The notation has been altered, but otherwise the extract is verbatim.

Experiments made by Guest confirm his theory, and the author (M. Finniecome) will show from an actual test on a pipe-bend that the theory agrees reasonably well with the value obtained from the above formula."

In the present paper, the correlation of the "Rankine" with the "Guest" theory has been indicated, and will be further discussed below. (The Saint-Venant theory is a refinement that will not be considered at present)..(51)

As the author interprets the extract, Guest's Law would seem to be deduced on reasoning as follows :—

From (49) The principal stresses are p,q, giving Max. Shear $=$ $\frac{1}{2}(p - q) = c$ say ....(52)

Result (50) implies that, as a shear, "c" may be caused by ($2c$, zero) as principal stresses, there is a "combined" stress (as it is called by M. Finniecome) of $2c$..(53)

The author has shown above, or believes he has shown, that pure shear "c" is concomitant with or caused by normals ($+c$, $-c$), although with some certain extra "fluid" pressure, an infinite combination of principal stresses ($F + c$, $F - c$) may cause a shear "c," such as ($4c$, $2c$), ($3c$, c) and so on ....(54)

There seems no especial reason why ($2c$, o) should be that functioning ....(55)

Only when friction is neglected is the plane of maximum shear the plane of fracture. Of course, if friction does not exist, (p', q') degenerating to p_1, q_1, where $\frac{1}{2}(p_1 - q_1) = c$ on the plane at 45° with the principal stress, but p_1 is not necessarily, and rarely is, $2c$ as stated in (50) .... (56)

It is conceivable that, at the surface of a test specimen, an ellipse $2c$, o exists, but it does not seem reasonable to assume such a very special condition as a general case................................(57)

FRICTIONAL-COHESIVE MATERIAL.

Author's Method.

Keeping (23) to (31) in mind, he argues as follows :—

Non-Cohesive Material with a friction angle ϕ and external load p_0 as a principal stress, is in equilibrium having the other principal stress q_0.

The principal plane for a perfect fluid is indeterminate, but for a non-cohesive frictional fluid, is determinate, being the direction of the primary applied stress, or is determined by the direction of the plane on which $n_0 \tan \phi$ must equal "s_0" if such plane is fixed or known............(58)

In the first stage in the deduction—

For Frictional-Cohesive Material, "c" may be treated as independent of the quantities existing previously.

An inclined* stress is introduced on a certain plane OR making an unknown angle with OP_0..........(59)

To deduce the angle between the Principal Plane and the Critical Plane, called here "ρ," the determining conditions are then applied, namely—

The ellipse of stress (p', q') to be deduced must fulfil the conditions on the critical plane

$$n' \tan \phi + c = s' \quad \text{.......... (60)}$$

$$\text{and } d/d\theta \, (n' \tan \phi + c) = s' \quad \text{.......... (61)}$$

The shear on the true principal plane must be zero..........(62)

The ellipse (p',q') deduced, represents equilibrium of internal stresses in the cohesive material, with "c" developed on the Critical Plane, though deduced by algebraical summation† of stresses external to p_0, q_0 condition ....(63)

From (60) and (61)—

$$c = \tfrac{1}{2} p' \tan \gamma/_2 - \tfrac{1}{2} q' \cot \gamma/_2 \quad \text{.......... (64)}$$

$$\text{that is } q' = p' \tan^2 \gamma/_2 - 2c \tan \gamma/_2 \quad \text{.......... (65)}$$

Result (64) may be known as the *General Equation.*‡

From (62) the direction of the principal stress may be determined, *but* (p', q') *cannot be to the same axes as* (p_0,q_0) *unless* $\rho_0 = 45°$, *which it cannot be for any real value of* ϕ..........(66)

The principles enunciated above will now be applied to several standard analyses, and existing standard analyses commented on, in the light of the suggested amended treatment.

First, will be considered a Frictional-Cohesive specimen under the breaking load in a Testing Machine.

---

* Inclined because a normal had to be introduced to provide for frictional effect of the normals concomitant with "c" as a shear.

† The method used bears some analogy to that for finding the stress in a redundant member of a truss.

The procedure there is as follows :—

Let C be the force in the redundant member R.

Presume C as an external force in the direction of R.

(*Note.*—The value of C depends on the externally applied loads, but is here assumed independent of them for the present.)

Find the stresses in the members of the truss as a determinate structure with R removed.

Due to External Loads .... (1)

Due to C .... (2)

Compute and add the movements (deflection) of the extremities of R due to (1) + (2) .... (3)

Equate (3) to the negative strain in R due to C and thus deduce C. An alternative analysis by the method of Least Work gives the same result. The analogy was suggested to the author by O. Fenwick, B.E.

‡ The modifications for negative q' and normals are investigated in "The General Equation of Stress" by the author.

Compression with Friction.

Navier's Theory.

This is the essence of all earthwork theories. The standard analysis will be stated and examined. In Navier's Theory,* due to friction and cohesion, the plane of rupture is taken at an angle of $\gamma/_2$ with the applied load which is assumed as a principal stress, and the cohesion " c " is connected with the applied stress by the relation† $t = 2c \cot \gamma/_2$.

The author takes a different view, and argues as follows :—There seems no doubt that for a frictional non-cohesive material the Critical Plane makes an angle $\gamma/_2 = (\pi/_2 - \phi/_2)$ with the applied stress........(67)

Nor is there any doubt that for cohesive material, neglecting friction, the maximum shear is on a plane at 45° with the principal plane, consequently the Critical Plane is at $\pi/_4$ with the applied stress........(68)

One would expect that, for a combination of friction and cohesion, the critical plane would lie at an angle between $(\pi/_4 - \phi/_2)$ and 45° with the direction of the applied stress..................................(69)

For the present purpose the cohesion " c " is the resistance to shear independent of normal stress (it implies, of course, resistance to tension or compression of the same intensity) and is assumed to be the same potentially on all planes. As a consequence, taking the critical plane as that where the curve of $n' \tan \phi + c$ touches the curve of s' (shear), and differentiating, " c " being a constant does not affect the result, the critical plane makes an angle $\gamma/_2$ with its own principal stress..........................(70)

The question is—In what direction, and what is the amount of the principal stress ?

The author reasons as follows :—

Principal Stresses give a " semi-graphical method of expressing the equilibrium of static stresses " : they are not permanent nor objective..(71)

In all natural phenomena one influence can be presumed to be superimposed on another, and the results should conform in whatever order the influences are applied. Now in a perfect fluid no‡ definite direction of principal stress exists..................................(72)

For frictional material the critical plane must make an angle $\gamma/_2$ with its principal stress. Again, for the reasons given, for frictional-cohesive material, the critical plane is still at $\gamma/_2$ with its principal stress, but the directions of the principal stresses may, and do, change..............(73)

---

* Morley, " Strength of Materials," p. 55 ; see also (78) later of this paper.

† The corresponding results are obtained for earthwork by A. L. Bell (Proc. I.C.E., vol. cxcix.), who presumes that the applied load is the principal stress in direction and amount.

‡ This, however, actually means that the applied stress (c.f. gravity) is the principal stress (neglecting cohesion) for infinitesimal friction.

It will be understood that the present discussion is dealing with material just about to move along a certain infinitesimal plane, but in equilibrium.

For a Frictional-Cohesive Test Specimen—The inclination of the plane of rupture is changed from 45° for a non-Frictional condition to an angle depending on ϕ and c.

Again the shape of the specimen would affect the angle of inclination since such depends on the potential " q "; again, if the ratio of diameter to length differs, in two specimens the possibilities of developing the planes of rupture are different.

This is found in practice. Fig. 11A shows diagrammatically the actual phenomena recorded with concrete. In a cube the inclination of the Plane of Fracture with the vertical approximates 45°, while, in a cylinder of length twice the radius, the angle may be 21°.

Presuming gravity as the load, if cohesion is absent, there is no influence to change the direction of the principal stress* from the vertical, and the internal resistance to shear, due to friction, functions to the extent of diminishing the amount of the other principal stress from p_0 to q_0....(74)

Now, if the shear due to cohesion, which is independent† of the applied stress, being an inherent property of the material, is applied on a certain plane (later to be the critical plane), it seems clear that for new conditions of equilibrium, that is, movement is just ready to begin on that plane mentioned, that the direction of the applied load (called p_0) is not necessarily a principal stress; in fact, the author argues that it is impossible to be so, since " c," introduced on the plane, must be caused by, or be concomitant with, " c " positive and negative normals, on planes at 45° with the plane on which " c " is introduced..(75)

Consequently (unless the critical plane makes an angle $\pi/_4$ with the principal plane), a shear must exist on the plane OR, *that is to say,* p_0 *is no longer a principal stress.* The position of the new principal stress is given by the relation that the shear caused by the normals $a + c$ and $a - c$, eliminate the previously existing shear, due to p_0, q_0 as a frictional material, on the new principal plane, and consequently the new principal plane lies at some angle (called " e ") with the direction of p_0..................(76)
The consequence of this is—

The ellipse p', q' is always inclined to that of p_0, q_0 by an angle " e," and is the ellipse representing internal stresses in equilibrium. Again, since the critical plane makes the same angle $\gamma/_2$ with its corresponding principal plane, both for non-cohesive and cohesive material, then the plane of rupture

* If the direction of the critical plane is fixed (as by a wall) the principal stress may move to conform with the necessary condition making an angle $\gamma/_3$ with the critical plane.

† Of course, for a certain applied breaking load, functions of ϕ, c, and applied load p_0 exist, connecting the various quantities. The value p_0 is that known as the "compressive strength"; it will vary with the dimensions of the specimen. The value of " c " is the resistance to shear. Pure tension, like pure compression, cannot cause shear. A pure shear c implies tension " c," and compression " c," respectively on each of the two planes at right angles to each other.

for cohesive material makes an angle* e' with the plane of rupture for non-cohesive material having the same characteristics apart from cohesion, and in earthwork a curve develops as shown in Fig. 12..............(77)

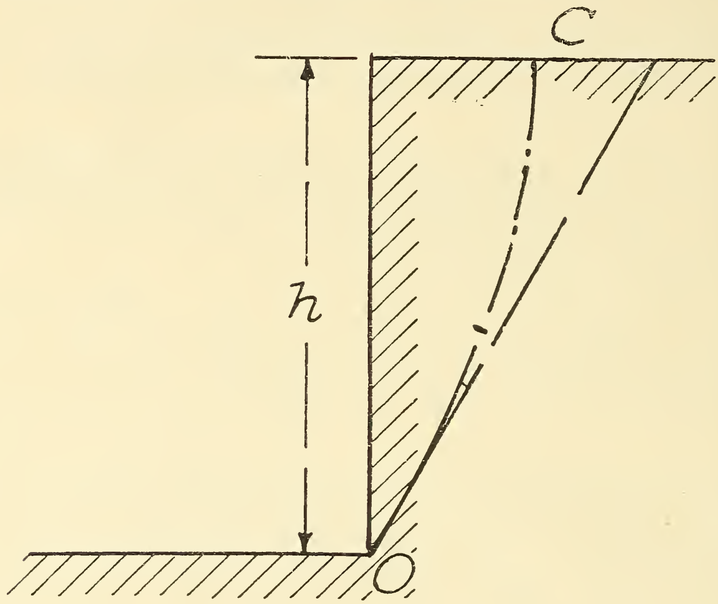


FIG. 12.

Morley's analyses will be examined now in the light of the author's views expressed above.

In his exposition of Navier's Theory, Morley ("Strength of Materials," p. 55), writes—

Normal stress on plane $= p \sin^2 \theta$ ....(i)
Shear stress on plane $= p \sin \theta \cos \theta$............(ii)
Resistance to shear $= \mu\ p \sin^2 \theta$..............(iii)

These could be true only if $q =$ zero ; and if p is a principal stress†....(78)
Actually, in the author's view,

Normal $= p' \sin^2 \theta' + q' \cos^2 \theta'$..........(iv)
and Shear $= \frac{1}{2}(p' - q') \sin 2\theta'$................(v)

Resistance to Shear $= \mu(p' \sin^2 \theta' + q' \cos^2 \theta')$..........(vi)
where p', q' are the principal stresses for the actual ellipse presuming friction, and θ' is the angle the plane makes with the principal stress p'...........

The maximum shear for any ellipse is always at 45° with the principal stress, being there $\frac{p - q}{2}$. For tension, if friction does not function, failure

* Near the surface of earth under gravity, the inclination of the critical plane with the principal plane for cohesive material is not $\gamma/_2$, owing to the fact that friction does not function when resultants are negative (Tension).

† That is to say, p cannot be the normal component of an applied inclined stress.

takes place of maximum shear, that is, at 45° with the line of applied stress ....(79)
$q = o$ implies that the ellipse of stress is a straight line, that is, that the intensities on every plane are in the same direction, i.e. along OP.

If q is given any value, positive or negative, the intensities on planes making a small angle with OP are nearly at right angles to OP instead of being along OP, as follows from the erroneous assumption of $q = o$.* Practically, a straight line as an ellipse is unattainable (even for negative values of q, up to a certain value, the normals are compressive, and friction may function). Actually $q = o$ may exist at one point intermediate between q positive and q negative.

It is necessary to take q as having a real value and deduce the resultant effects; then when q is infinitesimal, no anomalies arise............(80)

Alternatively—

Drawing a series of layers in the material as shown in the Sketch Fig. (13)—

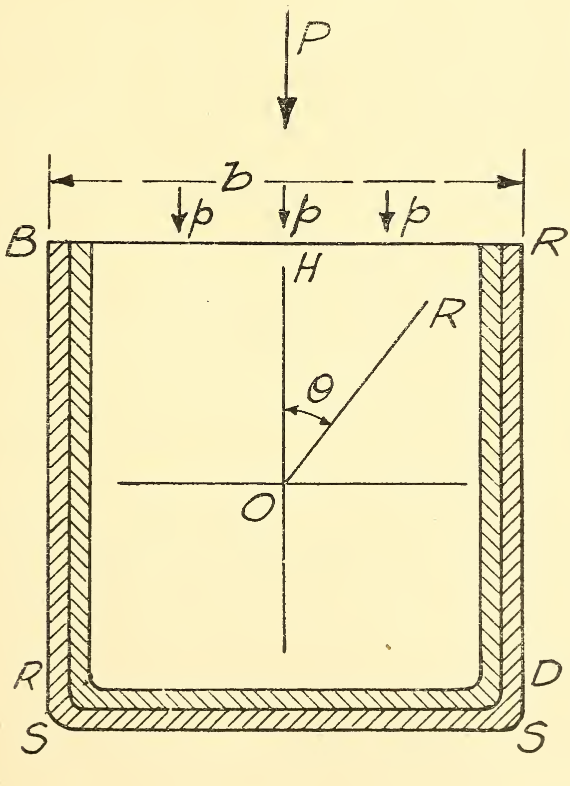


FIG. 13.

* A definite analogy exists with column analysis. In that analysis, the assumption that absolute zero exists, that is, that loading has zero eccentricity, and/or the column has zero initial bending, has caused much discussion, more or less futile; similarly with an assumption of a zero principal stress in earth pressure analysis. (*Vide* "Column Design Curves," Trans. I. E. A., vol. 9, by the author.)

(1) If the material is fluid, then $q = p$.

(2) If the material is fluid-frictional, that is, all resistance to tangential movement is proportional to the normal,* some lessening of q takes place, but the external influence introduced on fluid conditions only arises as a consequence of the application of "p," and thus *the new principal stress has the least value* consistent with equilibrium, that is, for a critical plane OR, $n \tan \phi = s$: from this $q_0 = p_0 \tan^2 \gamma/_2$................(81)

If cohesion is introduced on the fluid conditions, than "c" on any plane implies that the principal axis OP will be inclined to OP_0 and—

$$p_1 = p_0 + f(c_1\ \theta)$$
$$q_1 = p_0 - f(c_1\ \theta)$$

Such a condition might arise in non-homogeneous material......(82)

When the plane on which "c" is introduced is at 45° with OP_0, OP_1 and OP_0 are coincident,

$$\text{and } p_1 = p_0 + c$$
$$q_1 = p_0 - c$$

Only if $c = p_0$ can $q_1 =$ zero. See Fig. 14.

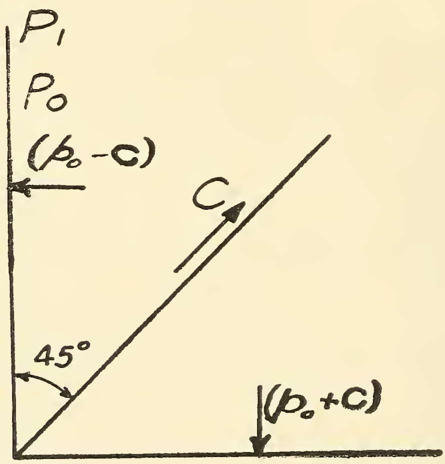


FIG. 14.

In such a case—

$$p_1 = 2c$$
$$q_1 = o \text{ ....(83)}$$

* Not necessarily as the first power, but it is assumed so in the present solution; the general reasoning is not affected thereby.

This, which is a limiting theoretic condition, unattainable probably, has been assumed as that for the general case in Guest's Law as expounded by M. Finniecombe in (50)....................................(84)

"Pressure in Clay," by A. L. Bell.

This analysis generalises on the limiting assumption of a constant direction of the principal stress, presumed the same, in direction and value, for a cohesive material as for a non-cohesive material; and is thus a Special Limiting Case.

If q_b is written for the concomitant principal stress when cohesion is present, then Mr. Bell's result becomes*—

$$q_b = p_0 \tan^2 \gamma/_2 - 2c \tan \gamma/_2 \quad \text{.......................(85)}$$

Without Cohesion—

$$q_0 = p_0 \tan^2 \gamma/_2 \quad \text{..................................(86)}$$

From the Generalisation of (64)—

$$q' = p' \tan^2 \gamma/_2 - 2c \tan \gamma/_2.$$

It is clear that Mr. Bell assumes p' to be coincident with p_0 in value and direction, also necessarily, that q' is coincident with q_0 in direction; that is, that a vertical plane only offers a resisting stress normal to itself. In other words, that the vertical plane is frictionless and non-cohesive. Thus it appears that the Bell results are those for a Limiting Case......(87)

It can easily be seen also, that the formulæ of Rankine, Navier, and Guest are for special limiting cases of the General Equation (64) obtained by writing "c," q, ϕ as zero respectively..............................(88)

The author considers that in its application to Earth Pressure, Strength of Materials, and other Engineering Problems, the General Equation is not limited by the restrictions of the Limiting Cases mentioned.

The limit of applicability of the General Equation is $q' = -c \tan \gamma/_2$, since with a larger negative value of q', the resultant on the critical plane is zero or negative, and the equations connecting q', p', and c are modified accordingly.†

Unsupported Bank.

As usually presented—

From the relation $p = 2c \cot \gamma/_2$

If w = weight of material

h = height of unsupported material, that is, the depth of the trench,

then failure will take place

when $wh = 2c \cot \gamma/_2$.

This is known as Scheffler's Analysis,‡ and has been re-deduced by Mr. Bell..(89)

* Pointed out by A. Burn, "Critical Planes," p. 225.

† See "The General Equation of Stress" by the author.

‡ Warren, "Engineering Construction," part i., p. 26.

From the Wedge of Rupture, or as shown otherwise by Prof. Ketchum—

$wh = 4c \cot \gamma/_2$.

If the analyses were correct, these two expressions, one of which is double the other, should be the same .... (90)

The author's treatment of the subject maintains that both results are wrong (though the latter has some approximation to that considered correct) .... (91)

The author's analysis gives a curve *CO* as that for failure at *O* in the sketch (see Fig. 12).

The height that a bank will stand unsupported should be deduced from this curve .... (92)

The characteristics of the commoner engineering materials will be used as illustrations.

MATERIALS UNDER TEST.

The applied load at failure in compression tests (in this deduction p_0) is known as the "Compressive Strength." *This "Compressive Strength" is not a basic unit for a certain material*; it is a function of the resistance to shear "c" (that is, the shear strength in pure torsion) and the angle of friction ϕ, also of the shape of the specimen; again, the inclination of the plane of rupture "ρ_v" to the direction of p_0 is a function of "c," "p_0," and ϕ, deduced in the author's treatment by using a subsidiary angle "e." This is seen in test specimens: the "compressive strength" of a cube (Fig. 11) is different for a cylinder having length equal to twice the diameter (Fig. 11A); a larger intensity is obtained with a larger specimen .... (93)

Cast Iron.

Compression.

The material has properties as follows* :—

Shear Resistance in Torsion, with failure at 45° with the axis of revolution
= 18,000 lb. per sq. in.

"Compressive Strength"
= 90,000 lb. per sq. in.

Tensile strength = 25,000 lb. per sq. in.

The Fracture Angle is of the order 35°. See Fig. 15.

Compression.

$$\text{Here } \frac{c}{p_c} = \frac{18000}{90000} = \cdot 2$$

$$\text{Since} \quad \sin 2e = \frac{c}{p_0}(1 + \sin\phi) \quad \textit{or}$$

$$\tan 2e = \frac{c}{p_c' = c\cos\phi}(1 + \sin\phi)$$

$$\text{Here} \quad \sin(\phi - 20^\circ) \quad \frac{1}{5}(1 + \sin\phi)$$

$$\therefore \phi = 39^\circ.$$

$$e = 9^\circ\ 30'.$$

* *Vide* "Merriman's Pocket-book," p. 277.

The various planes are shown in Fig. 15.

Tension.

The shear intensity can never reach the resisting capacity, so that failure is by direct tension.

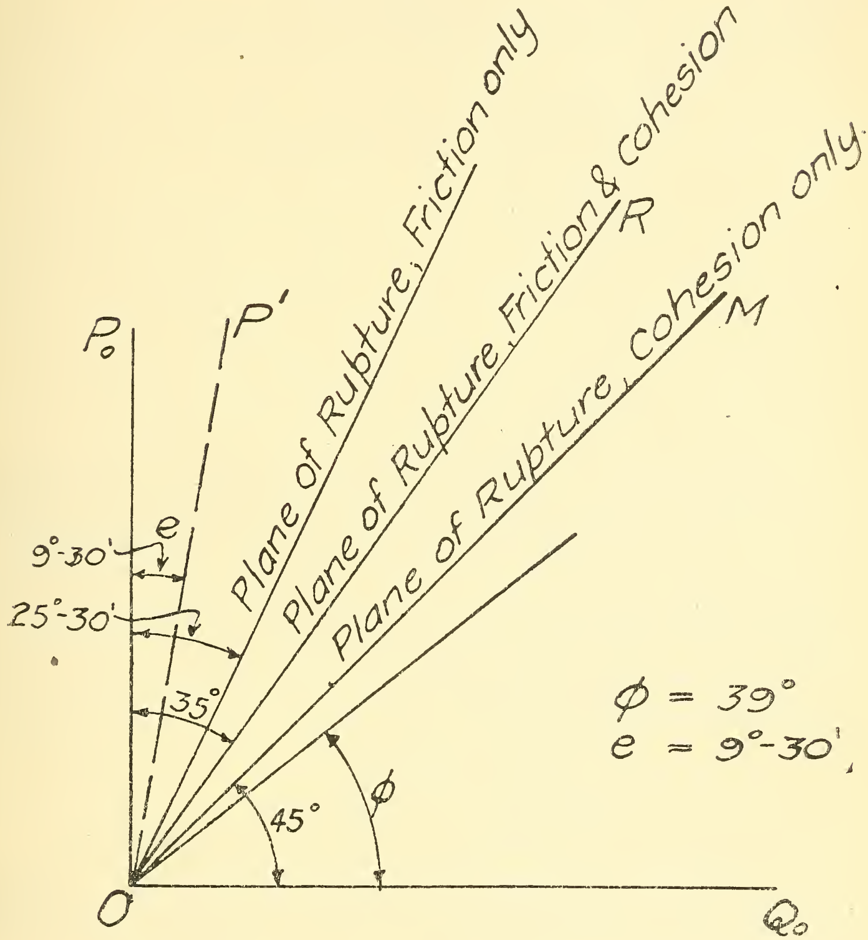


FIG. 15.

Steel has compressive and tensile strengths much the same, so that friction effects are small. This may be accounted for by the fact that during the process of manufacture high temperature and compressions are applied, to which subsequent pressures are small comparatively.

In tension, the phenomena have been examined above. In compression* the metal assumes fluid properties, i.e. plastic flow.

* The compression strength is deduced from beam tests. Fracture does not occur in compression.

Concrete is usually tested in compression.

" Compressive Strength," say 2,100 lb. per sq. in.

Shearing Strength, say 300 lb. per sq. in.

Evidently the value of the Friction Angle is high.

The Angle of Inclination of the Fracture plane is 21°.

$$\text{Here } \frac{c}{p_0} = \frac{1}{7}.$$

$$\sin(\phi - 48°) = \frac{1}{7}(1 + \sin\phi)$$

$$\phi = 64°.$$
$$e = 9°.$$

Figs. 11 and 11A, above, show typical results for concrete..........(94)

CONCLUDING SUMMARY.

To summarise: From primary facts—

If a material has cohesive resistance " c " to shear

Then movement may be caused on any plane, OR say, by applying
" c " as compression on one plane at 45° with OR, say OP.
" c " as tension on the other plane at 45° with OR, say OQ.

The stresses mentioned cause, or are concomitant with, shear ' c " on OR..(i)

It is not convenient to apply loads in this way.

Add F as a " fluid " pressure to (i).

Then $F + c$ on OQ, that is, p on OQ
$F - c$ on OP, that is, q on OP,
cause shear " c " on OA..............(ii)

(Normals F exist on all planes, but these do not affect shear.)

That is, if " p " be applied in a certain direction (c.f. vertical) and $q = (p - 2c)$ at right angles, the plane of max. shear is at 45° with OP ....(iii)

It will be noted above in (i) and (ii) that—

F may have any value

that is, p and q any value provided that

$q = (p - 2c)$..............................(95)

(If $F = c$, then $p = 2c$, and $q = o$, as assumed in (50) above, and so on.)

Also, that p and q may be in any direction, but that the critical plane is at 45° with the direction of p or q.

If friction does not function, and if zero on OP be attained, this is the end of the matter..(96)

Actually, however, a certain stress p_0 is applied normally to the material, and the material has cohesive resistance to shear " c " independent of any applied load, and a frictional resistance to shear proportional to whatever normal stress exists.

To have " p_0 " as a normal stress on one plane, and " c " as a shear on another plane, each independent of the other, an ellipse (p', q') must exist, whose axis is inclined to the direction of p_0 (*vide* Generalisation of "Bolt in a Bracket" case). " c " is introduced as independent of p_0, but the final ellipse p', q' deduced, represents internal equilibrium, and fulfils all the conditions laid down .... (97)

The solution of the ellipse for " c " as a function of p_0 is obtained by using the conditions—

(1) That, as a frictional material only, certain stresses exist throughout ;

(2) That to overcome cohesion other stresses must be introduced ;

(3) That an ellipse (p', q') representing equilibrium of stresses so deduced, is that to be used for getting relative values of variables .... (98)

The ellipse (p', q') deduced, representing the condition of equilibrium of stresses just before failure, that is, the limiting conditions are reached on one Critical Plane, determines the intensities on any plane for that moment of time .... (99)

In soils under gravity, a curved critical plane develops. The equation of this, and the many important results following, are developed in the author's paper " Critical Planes." In this present paper, the author has attempted to expound the basic change he suggests in the theory formerly accepted .... (100)

The Essential Oil of Eucalyptus Andrewsi from Queensland.

By T. G. H. JONES, D.Sc., A.A.C.I., and M. WHITE, B.Sc.

(*Read before the Royal Society of Queensland, 24th September, 1928.*)

Eucalyptus Andrewsi was named by Maiden with the record that it was common in the New England district of New South Wales and that it extended into Queensland, but with no definite locality assigned. Later he recorded it from Stanthorpe. Mr. C. T. White, who first brought the Queensland specimen under our notice, says that the tree is abundant on the road between Toowoomba and Crow's Nest, and that when he first obtained specimens he named it as a variety (var. *inophloia*) of *E. hœmastoma.* In the Toowoomba-Crow's Nest area it is known most commonly as "peppermint," though sometimes simply as "stringybark."

Examination of the essential oil obtained from leaves supplied through courtesy of the Forestry Department has shown it to be identical in chemical character with the oil of *E. Andrewsi* described by Baker and Smith,[1] and from this it would appear Mr. White's view expressed to us, that the tree named by him as a variety of *E. hœmastoma* (var. *inophloia*) is referable to *E. Andrewsi*, is correct.

The oil, which was obtained from the leaves to the extent of 1·25 per cent., consisted very largely of 1–α–phellandrene accompanied by relatively small amounts of p-cymene, piperitone (less than 5 per cent.), piperitol, and aromadendrene, and in view of high phellandrene content is therefore of economic value. Cineol and pinene were not detected.

EXPERIMENTAL.

170 lb. of leaves from Peachey, collected at the end of October 1927 and distilled for several hours in steam, gave 1,100 ccs. of oil possessing an agreeable phellandrene odour.

The following constants, indicative of high phellandrene content, were recorded. Those of *E. Andrewsi* (Smith) are also appended for comparison.

		E. Andrewsi.	
$d_{15\cdot5}$	·8770	$d_{15\cdot5}$	·8646
$[\alpha]_D$	–60·9	$[\alpha]_D$	–41·5
n_D^{20}	1·4810	n_D^{20}	1·4831
Acid number	nil		
Ester value	14·22		
Acetyl value	56·24	Acetyl value	57·67

[1] Research on the Eucalypts, Baker and Smith, second edition, p. 303.

300 ccs. were fractionated at 4 mms. pressure using a 12 pear column and the following fractions collected :—

					$d_{15\cdot5}$	α_D	n_D^{20}
(*a*)	0	–	50° C	212 ccs.	·8516	–63·5	1·480
(*b*)	50°	–	70° C	30 ccs.	·8815	–42	1·4832
(*c*)	70°	–	80° C	36 ccs.	·9329	–35	1·4845
(*d*)	80°	–	105° C	18 ccs.	·9592	–19	1·4990

Fraction (*a*), which constituted the bulk of the oil, was extracted with 50 per cent. resorcin solution, but no cineol could be detected in the extract. Further refractionation failed to show any appreciable quantity of pinene, and all tests for this terpene were negative. The presence of 1–α–phellandrene was confirmed by the usual nitrosite reaction. As commercial phellandrene is recorded as containing p-cymene it appeared of interest to examine this fraction for this constituent. Removal of the bulk of the phellandrene by repeated nitrosite formation gave a residue which, after distillation several times over sodium, showed the constants recorded for p-cymene, viz., b.p. 175° C $d_{15\cdot5}$ ·8662, n_D^{20} 1·485. Identity with this substance was confirmed by oxidation to p-hydroxy isopropyl benzoic acid m.p. 155·5° C.

The crude phellandrene examined in this way showed a cymene content of approximately 10 per cent.

Fractions (*b*) and (*c*) were taken separately with neutral sodium sulphite solution to extract piperitone and the residue again fractionated. Further phellandrene was separated, leaving a residue which possessed the constants recorded for piperitol, viz. $d_{15\cdot5}$ ·9345 n_D^{20} 1·482. (Found C 77·9 H 11·6. Required C 78·1 H 11·2.) The amount available was too small for further examination.

Piperitone.—Separated from the sulphite solution the absorbed oil possessed the characteristic odour of piperitone. The following constants were recorded :—

$d_{15\cdot5}$ ·9375, n_D^{20} 1·4816$[\alpha]_D$–6

(Found C 78·5 H 10·4. Required C 78·9 H 10·5.)

Identity with piperitone was confirmed by reduction with sodium amalgam and alcohol to the dimolecular ketone M.P. 148° C. Preliminary examination of the original oil by bisulphite extraction indicated a piperitone content not greater than 5 per cent.

Fraction (*d*) was distilled several times over sodium and again fractionated. Phellandrene was still present but the bromine acetic acid reaction for sequiterpene was well pronounced, and some sesquiterpene, presumably aromadendrene, was therefore present in traces only in the oil.

The authors wish to express their thanks to Mr. C. T. White for suggesting this investigation.

Petroleum from the Roma Bores.

By J. B. HENDERSON, F.I.C., and W. J. WILEY, M.Sc.

(*Read before the Royal Society of Queensland, 29th October, 1928.*)

In 1897 the first bore at Roma was sunk to a depth of 1,678 feet to obtain a supply of water for the town. To obtain a further supply a second bore was sunk close to No. 1 and in October 1900 reached a depth of about 3,700 feet. At this depth a flow of natural gas was obtained. This gas had a smell resembling kerosene. An analysis of the gas made in the Government Chemical Laboratory in 1900 by the old absorption methods showed the presence of hydrocarbons other than methane. The results summarised were as follows :—

	Per cent.
Carbon dioxide	1·5
Marsh gas (CH_4)	72·0
Ethane and other hydrocarbons	23·1
Inert gases (by difference)	3·4
	100·0

Although we did not then know it, those results were conclusive proof that the gas was a petroleum gas and not a coal-seam gas. Much work done on natural gases in America has shown that coal-seam gas does not contain hydrocarbons other than methane while petroleum gas does. The gas was accompanied by a considerable amount of water, the yield of gas having been estimated at about 70,000 cubic feet per day and of water at 183,000 gallons per day.

The gas was allowed to run to waste for nearly six years. The Roma Town Council then reticulated the town to supply the gas to householders. The gas was connected up in June 1906, but unfortunately it ceased to flow within a very short time of being diverted through the separator into the gasometer. Obviously the checking of the flow by the separator caused the water to accumulate in the bore until its pressure choked off the gas. Reports were published in the newspapers that when the gas ceased there was some light clear oil found floating on the water for a very short time after the gas-flow ceased. Unfortunately no samples of the oil could be obtained officially later, nor other absolutely direct evidence about the oil. Its occurrence, however, is quite in accordance with its being a condensate from the gas when the rate of flow was being choked down by the accumulating water, with the resultant greater cooling of the gas and condensing of the heavier vapours.

A company was then formed and a third bore put down in the same vicinity. In October 1908 this bore also got gas at about the same depth, 3,700 feet. The gas, however, caught fire immediately after coming in and burned down the derrick. The fire was extinguished, but the gas soon ceased to flow through water arising, and the bore was abandoned. No sample of this gas was analysed.

The Government then put down a fourth bore in the same vicinity, and got gas also at about 3,700 feet, in August 1920. The flow of gas when partly shut off to give 87 lb. pressure at the outlet valve was not less than 10,000,000 cubic feet per day, accompanied by 100,000 gallons of water in the same time. This water was more saline than any of the waters which any of the bores had passed through in the higher strata. It is to be noted that these three bores which gave petroleum gas are so close that a circle of 200 yards diameter would easily include all of them.

This gas from No. 4 Bore gave the following results on analysis :—

	Per cent.
Carbon dioxide	1·0
Methane	63·2
Ethane and other hydrocarbons	27·0
Inert gas	8·8
	100·0

The specific gravity of the gas, air being taken as 1, was 0·65 by the Schilling diffusiometer.

Professor Steele, of the University of Queensland, found helium among the inert gases. He estimated the proportion as about 1 part in 12,000.

The gas when extracted with mineral seal oil in absorbers gave petrol at the rate of about 150 gallons per 1,000,000 cubic feet per day, a proportion which should prove of great economic value. Work ceased in 1922 on this, the third bore which had got gas from the same geological horizon. This bore became blocked, and while trying to clear it a showing of heavy petroleum was obtained at about the 2,750-foot level. A sample of this petroleum, which is a soft, dark-brown wax at ordinary temperatures, is shown on the table.

A fifth bore was put down close to the others by the Roma Oil Corporation, and a flow of gas was obtained at about the same level, in September 1927. This gas had a similar composition to that previously found in the other bores, and was found to contain about the same yield of petrol, 1·2 pints per 1,000 cubic feet. Its specific gravity was also 0·65 by the Schilling diffusiometer (air = 1).

The flow of gas, with the opening adjusted to give a pressure of 450 lb. per square inch at the top of the casing, was about 600,000 cubic feet per day.

The bore is 3,701 feet deep. The 8-inch casing is cemented in at 3,555 feet, shutting off all gas and water above that depth. The hole is not cased below that level, the bottom 146 feet being "open hole." Gas was obtained during the last 42 feet bored. In the Government Bore (No. 4, Roma) where a mud fluid was not used in the boring to fill the pores of the strata, gas was obtained during the last 100 feet.

A 3-inch swabbing tube extends down for about 3,000 feet. The swabbing tube is connected gastight to the top of the 8-inch casing, and the outlets from both are controlled by valves.

The valve of the 3-inch tube is opened on every second or third day for a short time. Water is blown up, accompanied by a little light oil. Obviously there must be water in the lower part of the bore above the level of the bottom of the swabbing tube, and the upward rush of the gas carries the water and oil with it exactly as in an ordinary " air lift " for water.

This water must of course be entering the bore below the level of the 8-inch casing; probably it is coming from the same stratum as the gas. It is much more saline than any water in the upper strata. The most saline of these contained 25 grains of chlorine (calculated as sodium chloride) per gallon, while the water accompanying the gas contained 212 grains of chlorine per gallon (calculated as sodium chloride). The amount of water blown up the tube depends on the time during which the blowing is continued. For the first twenty days it was about 4,200 gallons, or an average of 210 gallons per day. As the water rose high enough in the bore on several occasions during the first few months to stop the flow of gas, evidently it was coming in at a slightly greater rate than it was being blown out.

The water was not often much emulsified with the oil, and the bulk of the emulsion generally separated rather quickly and easily. A proportion of the emulsion was occasionally rather persistent, and was broken up by heating with a steam coil.

The emulsion was coloured blue-black as it reached the surface. It was noticed that, if the oil containing the emulsion were left exposed to the air, a brown-red deposit of ferric hydroxide was obtained and the black colour disappeared. The black deposit was ferrous sulphide, which oxidised to ferric hydroxide. Obviously, the oxygen from the air dissolves in the oil and oxidises the sulphide.

The oil obtained from this bore, amounting to about 10 gallons per day over the first six months of the flow, probably caused more interest than any of the other facts about the bore. It is a clear, volatile liquid, about midway in its properties between the ordinary petrol and the kerosene of commerce. This volatility, coupled with the small amount obtained, and other factors, suggested that gas without oil enters the bore, and that, as the gas cools on expanding and rising, it deposits the oil, i.e., that the oil is a condensate. In order to test this hypothesis, the following work was done on a sample of the Roma oil received in the Government Chemical Laboratory in November 1927.

The volume of vapour of a given liquid which can be carried by a gas at a given temperature and pressure is a function of the vapour pressure of the liquid at that temperature. Dalton's "Law of Partial Pressures," as applied to vapours, can be stated in the form :—

$$\frac{\text{Volume of vapour}}{\text{Total volume}} = \frac{\text{Pressure of vapour}}{\text{Total pressure}}$$

Hence, knowing the total pressure, total volume (i.e., volume of gas and vapour), and vapour pressure, the volume of vapour which can be carried by the gas is readily calculated. Knowing the vapour density and specific gravity of the liquid vapourised, the weight of vapour can be calculated and from this the volume of liquid corresponding to the calculated weight of vapour.

The Roma oil, however, consists of a mixture of many liquids, and the above calculation could not be applied directly to such a mixture. Therefore, the first work done on the sample of oil was a fairly thorough fractional distillation, splitting it up into a number of fractions having a boiling point range of 5° C. Each of these fractions on partial evaporation would yield a vapour phase approximating in composition to the remaining liquid portion of the fraction, and a calculation, from the vapour pressure, of the volume of its vapour in a gas would be approximately correct.

The experimental work, therefore, involved a fractional distillation of the oil in order to split it up into fractions of small boiling-point range, and the determination of the vapour pressure, vapour density, and specific gravity of these fractions.

The results of this experimental work are shown in the following table, the experimental methods and details being given in the Appendix :—

TABLE I.

Fraction.	Boiling Point °C.	Proportion Present in Oil.	Vapour Pressure M.M., of Mercury.				Vapour Density, Lb. per Cub. Ft. of Vapour at N.T.P.	Molecular Weight.	Specific Gravity at 27°C.
			180°F.	160°F.	150°F.	100°F.			
		Per Cent.							
1	Start to 100°C.	3·21	..	..	..	..	0·276	99	0·722
2	100–105	0·78	..	..	..	..	0·290	104	0·745
3	105–110	0·69	..	..	..	..	0·307	110	0·742
4	110–115	0·89	..	..	..	..	0·318	114	0·736
5	115–120	3·32	258	180	153	55	0·327	117	0·743
6	120–125	4·03	227	150	122	39	0·327	117	0·754
7	125–130	1·93	193	131	107	35	0·335	120	0·763
8	130–135	3·12	155	103	83	23	0·349	125	0·761
9	135–140	5·35	132	81	65	19	0·363	130	0·755
10	140–145	3·53	114	75	61	19	0·369	132	0·756
11	145–150	4·71	104	69	58	19	0·374	134	0·766
12	150–155	5·56	86	60	53	19	0·383	137	0·773
13	155–160	10·80	75	50	43	17	0·394	141	0·768
14	160–165	9·59	61	41	34	11	0·408	146	0·768
15	165–170	5·39	58	39	33	11	0·413	148	0·778
16	170–175	5·78	55	36	31	11	0·427	153	0·782
17	175–180	5·05	43	33	18	5	0·438	157	0·780
18	180–185	4·29	41	16	12	2(?)	0·450	161	0·783
19	185–190	3·35	..	..	..	..	0·458	164	0·789
20	190–195	3·21	..	..	..	..	0·464	166	0·793
21	195–200	2·23	..	..	..	..	0·480	172	0·797
22	200–210	3·87	..	..	..	..	..	..	0·802
23	210–220	2·83	..	..	..	..	..	..	0·804
Residue	220–	6·52	..	..	..	..	..	..	0·827

The other factors necessary for the calculation as to whether the oil can be carried as vapour in the gas are—

(*a*) Daily flow of gas—Mr. Ross's determination of 600,000 cubic feet (at N.T.P.) per 24 hours when the rate is adjusted to give 450 lb. pressure is taken.

(*b*) Pressure in 8-inch casing at top of bore—450 lb. per square inch noted from gauge.

(*c*) Pressure in gas strata at bottom of bore—1,400 lb. per square inch, estimated by Mr. W. A. Cameron and Mr. Ogilvie.

(*d*) Temperature in 8-inch casing at top of bore—Mean taken at 100° F.

(*e*) Temperature in gas strata at bottom of bore—Estimated by Mr. Ogilvie at 160° F. (Temperature at bottom of near-by Government oil bore determined by Mr. W. A. Cameron in 1920, 180° F.)

Fraction 14 can be taken for an example of the calculation used for each fraction.

For fraction 14—

Specific gravity	= 0·768
Vapour density	= 0·408
Vapour pressure at 160° F.	= 41 m.m. of mercury
	= 0·79 lb. per square inch
Vapour pressure at 100° F.	= 11 m.m. of mercury
	= 0·21 lb. per square inch.

At 1,400 lb. pressure and 160° F., 600,000 cubic feet (measured at N.T.P.) of gas would be capable of carrying $\frac{0 \cdot 79}{1400} \times 600{,}000 = 338$ cubic feet of the vapour of fraction 14 (measured at N.T.P.). 338 cubic feet of this vapour would weigh $338 \times 0 \cdot 408 = 138$ lb. This amount stated in gallons is $\frac{138}{10 \times \cdot 768} = 18$ gallons.

Each 600,000 cubic feet of gas in the strata, taking the pressure at 1,400 lb. and the temperature at 160° F., is therefore capable of containing the vapour of 18 gallons of that part of the oil represented by fraction 14.

A similar calculation shows that the gas, when the temperature has fallen to 100° F. at the top of the bore and the pressure has fallen to 450 lb. per square inch, would only be capable of containing as vapour 14·8 gallons of that part of the oil represented by fraction 14.

In other words, if, under the conditions stated, the gas in the strata were saturated with the vapours of fraction 14, it would deposit 3·2 gallons of that fraction for each 600,000 cubic feet of gas which came up the bore.

It is here assumed that there is only gas at the bottom of the bore. If the gas is flowing through a liquid another case presents itself. For a mixture of such closely related hydrocarbons it can be assumed that Henry and Ranalt's Laws will approximately hold. That is, that the vapour pressure of each constituent in the mixed " oil " will be proportional to its concentration in the oil. To illustrate the calculation in this case we will again take fraction 14.

Fraction 14 is present in the oil in the proportion of 9·59 per cent. Its vapour pressure when in equilibrium with the oil at 160° F. then will be $\frac{9·59}{100} \times 41$ m.m. By continuing the calculation exactly as before, we find that 600,000 cubic feet of gas would carry 1·72 gallons of this fraction.

At 100° F., 1·42 gallons could be carried.

A similar calculation for each of the other fractions of which the vapour pressure was determined yields the following results :—

TABLE II.

Fraction.	Boiling Point °C.	Proportion Present in Oil.	Gallons of Fraction which could be held as Vapour by 600,000 Cub. Ft. of Gas (Measured as N.T.P.)		Gallons Actually Yielded by 600,000 Cub. Ft.	Gallons which could be held in Equilibrium with the Liquid	
			At 160°F.	At 100°F.		At 160°F.	At 100°F.
5	115–120	3·32	65·3	61·5	0·332	2·17	2·04
6	120–125	4·03	53·8	43·4	0·403	2·17	1·75
7	125–130	1·93	47·7	42·2	0·193	0·92	0·81
8	130–135	3·12	39·4	26·8	0·312	1·23	0·84
9	135–140	5·35	32·2	23·7	0·535	1·72	1·27
10	140–145	3·53	30·3	24·0	0·353	1·07	0·85
11	145–150	4·71	28·2	24·0	0·471	1·33	1·13
12	150–155	5·56	24·7	24·5	0·556	1·37	1·36
13	155–160	10·80	21·4	22·5	1·080	2·31	2·43
14	160–165	9·59	18·0	14·8	0·959	1·72	1·42
15	165–170	5·39	17·4	14·9	0·539	0·94	0·80
16	170–175	5·78	16·2	15·3	0·578	0·94	0·88
17	175–180	5·05	10·8	7·3	0·505	0·55	0·37
18	180–185	4·29	7·7	..	..	..	..
	Total ..	72·45					

It will be seen that for all the fractions of the oil examined (with the exception of fraction 13) the gas in the strata could contain vapours of these liquids which would, if the gas were saturated, deposit as the gas cooled and expanded on coming to the surface. Taking these figures in conjunction with the proportion of each 5°C. fraction found in the oil and the daily yield of oil (about 10 gallons), it will be seen that the gas in the strata contains a fairly high proportion of the possible amount of the less volatile fractions. A proportion of the vapours of the higher boiling-point fractions condenses in the bore as the temperature decreases, and the condensed liquid absorbs some of the vapours of the more volatile fractions. As these fractions condense they flow down to the water, and come up with the gas and water when the pressure is released at the top of the 3-inch swabbing tube.

The results show that a yield of about 10 gallons per day could be quite easily obtained by condensation of vapours from the gas under the conditions stated. They also indicate that under these conditions the " oil " exists in the strata as vapour in the gas.

The work done on this " oil " naturally brings up the question as to whether such clear, light oils, which are found in a very few widely separated places, are condensates or filtrates. Hitherto geologists seem to have been content to treat them as filtrates, assuming that by some unexplained but long-continued process of filtration the heavier asphaltic material and the less volatile components of the ordinary crude oil are removed, only the volatile and lighter fractions passing on. Until lately practically nothing was known to the chemists or physicists which would support such a contention. Lately, however, work on adsorption by silica gels has given remarkable separations, which suggest at least possibilities if not probabilities of facts being disclosed which might explain at least part of the separation of the heavier constituents of the crude oil from the lighter constituents.

A much simpler explanation requiring no assumptions of unknown or unexplored properties of " rock " materials is illustrated by the work just described.

It is recorded in the text-books that strata containing crude oil have generally a higher temperature than surrounding rocks which do not contain crude oil. The methane, ethane, and other gases above the crude oil in the sandstone or other porous rock must obviously, through long contact, be saturated at that temperature and pressure with the vapours of every volatile constituent of the crude oil, the lighter fractions of course supplying more vapour.

Being gases, they would travel more quickly through the pores of the rock than the liquid. As they left the warmer crude oil centre for the colder rocks, the fall in temperature would result in the condensation of those vapours with which the gas was saturated, until the saturation point had again been reached for each constituent at that temperature. The liquid so deposited would obviously be a clear, light oil practically free from the heavier much less volatile constituents. It would increase in bulk by the dissolving in it to saturation point, at that temperature and pressure, of all the constituents of the gas, including the light vapours.

As the gas can obviously pass for a long way from the main crude oil deposit, it can easily convey from that crude oil much light oil in the form of vapour, and deposit part of that vapour as liquid oil again when and where the temperature falls sufficiently.

This fractional distillation action would explain the fact that oil is sometimes found lighter on the outskirts of an oil deposit. The gas travelling ahead of the crude oil carries the lighter vapours with it ; these are condensed by cooling and dilute the crude oil which follows. In such cases the yield of lighter crude oil is followed by the flow of the heavier oil from the centre. When a bore penetrates the main oil deposit such a change in composition would not be noted.

It is not at all unlikely, in the very varying conditions which prevail in the different petroleum deposits, that in some instances filtration or adsorption may be a factor in the creation of deposits of light clear oil.

It seems, however, much more probable that in the great majority of cases it is the condensation of vapours by the cooling of saturated gases which is the main factor. Such condensation may take place in the rocks, or, as in the local case just described, in the bore casing.

The determination of whether a light oil is a filtrate or condensate is of importance to the geologist, as one of the factors to be included in forming an opinion as to the possible or probable distance or direction of the original crude oil deposit from which the light oil has been derived.

APPENDIX.

The Experimental Methods used in obtaining the Properties of the Roma Petroleum given above.

Fractional Distillation.—A 10-litre sample of the oil was taken for fractionation. This was distilled from a 4-gallon copper still through a fractionating column 120 cm. long by 4 cm. diameter, packed with ¼-inch Lessing Rings. After the first fractionation the fractions were systematically redistilled through the same column. As no breaks occurred in the distillation curve, fractions were separated over 5° C. boiling-point range. The fractions were redistilled a third and fourth time through a column 115 cm. long by 1·8 cm. diameter, packed with ¼-inch Lessing Rings.

The results of these four distillations, together with a standard A.S.T.M. distillation, are shown graphically in Figure 1. Owing to a leakage in the cork at the bottom of the fractionating column, there was 11 per cent. loss in distillation 2, as against less than 2 per cent. loss in any other distillation. As the leakage was below the column and occurred over nearly the whole range of boiling, it probably did not materially affect the proportions of the various fractions obtained.

As the last three distillations did not show promise of much further material separation, the results of the fourth distillation were taken as suitable for the present purpose. These figures, corrected for losses, are given in Table I. of this paper, page 137, 2nd and 3rd columns.

Vapour Pressure of Fractions.—Determinations of the vapour pressure of the fractions at temperatures from about 100 to about 180° F. were made, and the results are shown in graph form in Figure 2.

The apparatus used is shown diagrammatically in Figure 3. It consisted of two barometer tubes, "A" and " B " 80 cm. in length, connected by a U tube to a mercury reservoir " C." The method of closing the top of the tubes is shown in the detail drawing. The barometer tube and a smaller tube " D " were drawn down so as to correspond roughly, and then ground to a tight joint. With mercury placed above the constriction in the barometer tube and the tube " D " seated, there was no leakage of mercury into the barometer after considerable standing, and the air was effectively sealed off. Tube " B " was water-jacketed.

In use the reservoir " C " was raised to the level of the top of the tubes, the plug in " B " removed, and about 1 c.c. of the liquid whose vapour pressure was to be measured was introduced on top of the mercury in " B." This was then lowered and raised so as to rinse out any liquid left from a preceding experiment. After rinsing out thus several times, the mercury level was adjusted so as to enclose about 1 c.c. of the liquid below the valve, which was then closed and sealed with mercury.

On lowering " C " to the level of the bottom of the barometer tubes we now have "A" as a comparison barometer and " B " as a barometer with about 1 c.c. of the liquid floating on top of the mercury. The difference in level between the mercury in "A" and " B " is measured, and is the vapour pressure of the liquid at the observed temperature (subject to corrections described later).

Trouble was experienced with the different fractions owing to their containing dissolved gases which were liberated when in the vacuum of the barometer tube. These of course exert a pressure, and have to be blown out before taking a vapour pressure reading.

When taking a series of readings the apparatus was prepared as above, and boiling water poured through the water jacket, which was closed when full of the hot water. The reservoir " C " and valve were now regulated so as to blow out the gases which had been liberated from the sample in " B." The difference in height between the mercury columns in "A" and " B " was now measured as the temperature of the water jacket slowly fell.

Corrections.—The weight of the actual oil in " B " corresponded to less than 1 mm. of mercury pressure and was neglected. The other two important corrections are for surface tension effects and for the expansion of mercury in the heated column, making it lighter than in column "A." The surface tension effect is uncertain, although by no means negligible. As, however, on the bulk of the fractions tested it was less than 5 per cent., no allowance was made. The mercury expansion was corrected for by adding to the vapour pressure measured a quantity equal to $(L \times \cdot 000818\ t)$ where L is the length of the heated column of mercury and t the difference in temperature between "A" and " B." This correction amounted to 5 mm. of mercury for some samples at 180° F. At 100° F. it was only about 1 mm. for all the samples.

The uncorrected vapour pressure results are shown in Figure 2. The corrected pressures used in the calculation are shown in Table I.

The vapour pressure of fractions 1 to 4 were not determined, as they were present in the oil in such small proportions. The fractions above 18 had such small vapour pressures that they could not be satisfactorily determined by the method described.

Accuracy.—The apparatus and the method of working were not designed for a high degree of accuracy. Water, with its accurately known vapour pressure, was used for checking the apparatus and method of working. In these control tests with water the greatest variation noted from the recorded standards was 5 per cent. With some of the oil fractions the working error would probably be a little greater than with water. In the higher fractions where the vapour pressure is only a few millimetres, the working error of this apparatus and method would be appreciably higher than 5 per cent. As, however, sufficient information was being obtained from the other fractions, and as considerable time would have had to be spent in getting together and testing the necessary apparatus for the accurate determination of the vapour pressure of these higher fractions without any adequate return from the extra information gained, it was decided to go no further with these determinations. Further results obviously could not materially affect the conclusions drawn from these experiments.

It is to be remembered that the vapour pressures were not made on a liquid which was a pure definite chemical compound with a constant boiling point, but on a mixture of liquids covering a range of 5° C. in boiling points. The results obtained in these circumstances must depend somewhat on the manipulation.

Vapour Density of Fractions.—The method adopted was the modified Duma's method in which the flask containing the vapour is not sealed prior to weighing. A narrow tube which was drawn out to a fine top was sealed to a glass flask of about 120 c.c. capacity. The volume of the flask was determined by the weight of water which it contained.

In making a determination a volume of about 10 c.c. of the fraction whose vapour density was being determined was introduced into the flask, which was then immersed almost to the top in a glycerine bath at from 20 to 30° C. above the boiling point of the liquid. When vapour ceased to emerge from the flask it was withdrawn from the bath, quickly cooled, washed, dried, and weighed. As air enters the flask when the vapour condenses, there is no necessity to make a buoyancy correction. The weight of vapour filling the flask, the temperature and pressure (atmospheric), and the volume of the flask being known, the vapour density is easily calculated.

Table I. shows the vapour density in pounds per cubic foot at N.T.P. and the corresponding molecular weights of the fractions.

Specific Gravity of Fractions.—This was determined by the usual method of weighing a plummet in air and then in the liquid. The specific gravities are shown in Table I.

Figure 1.

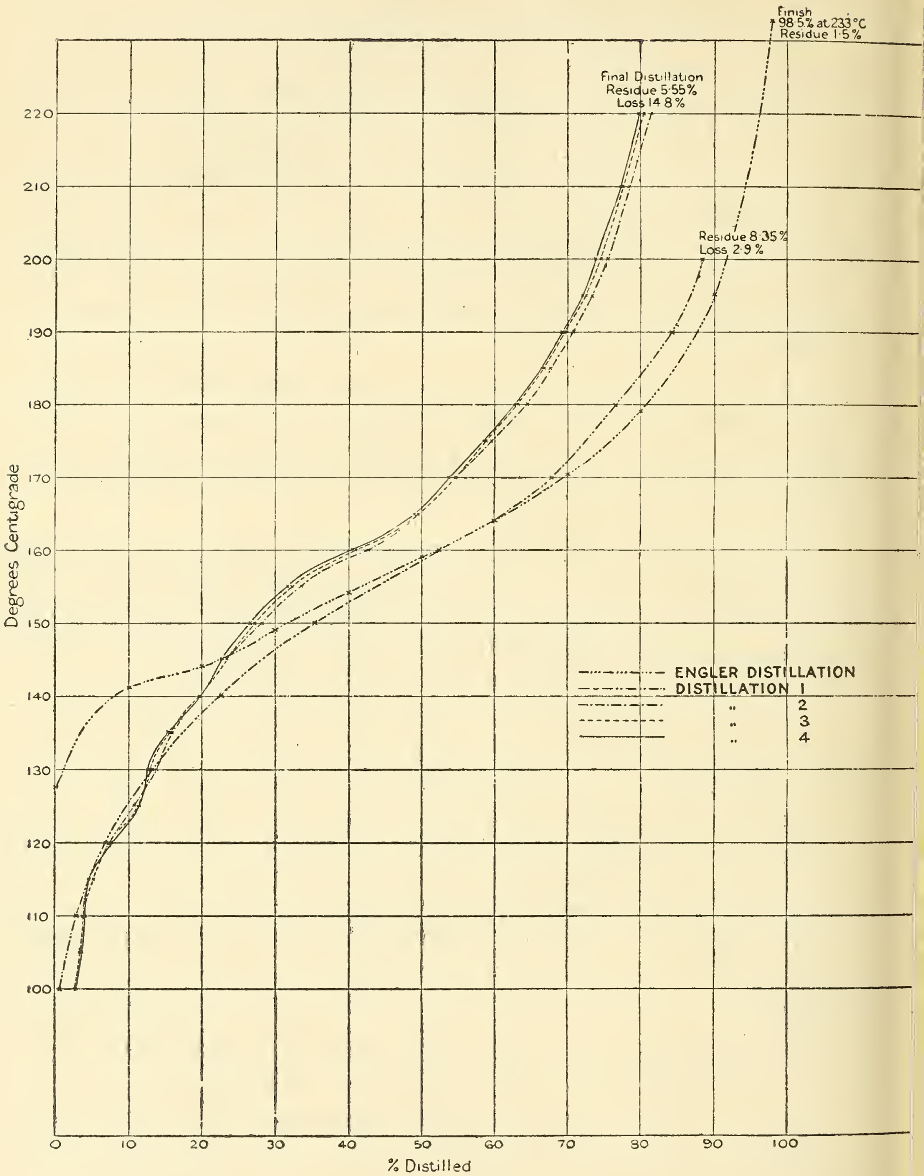
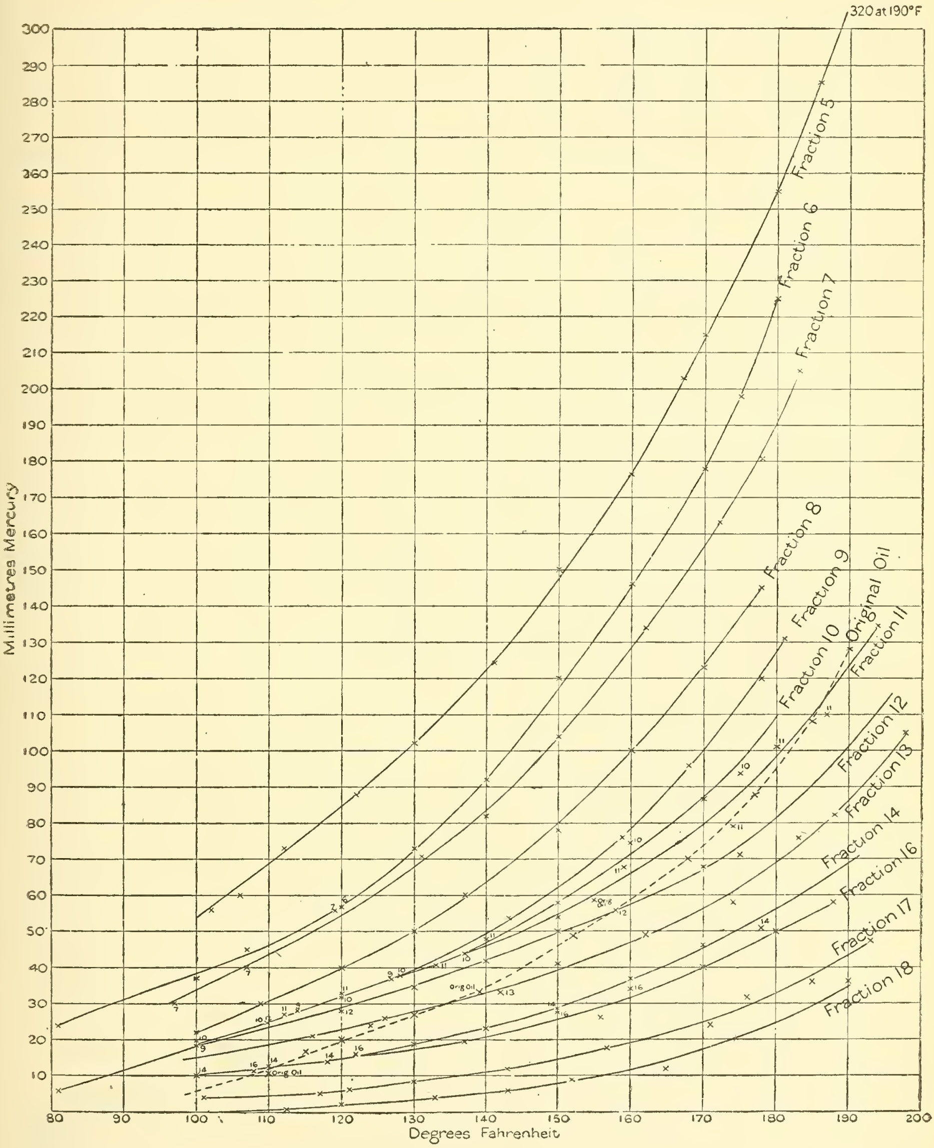
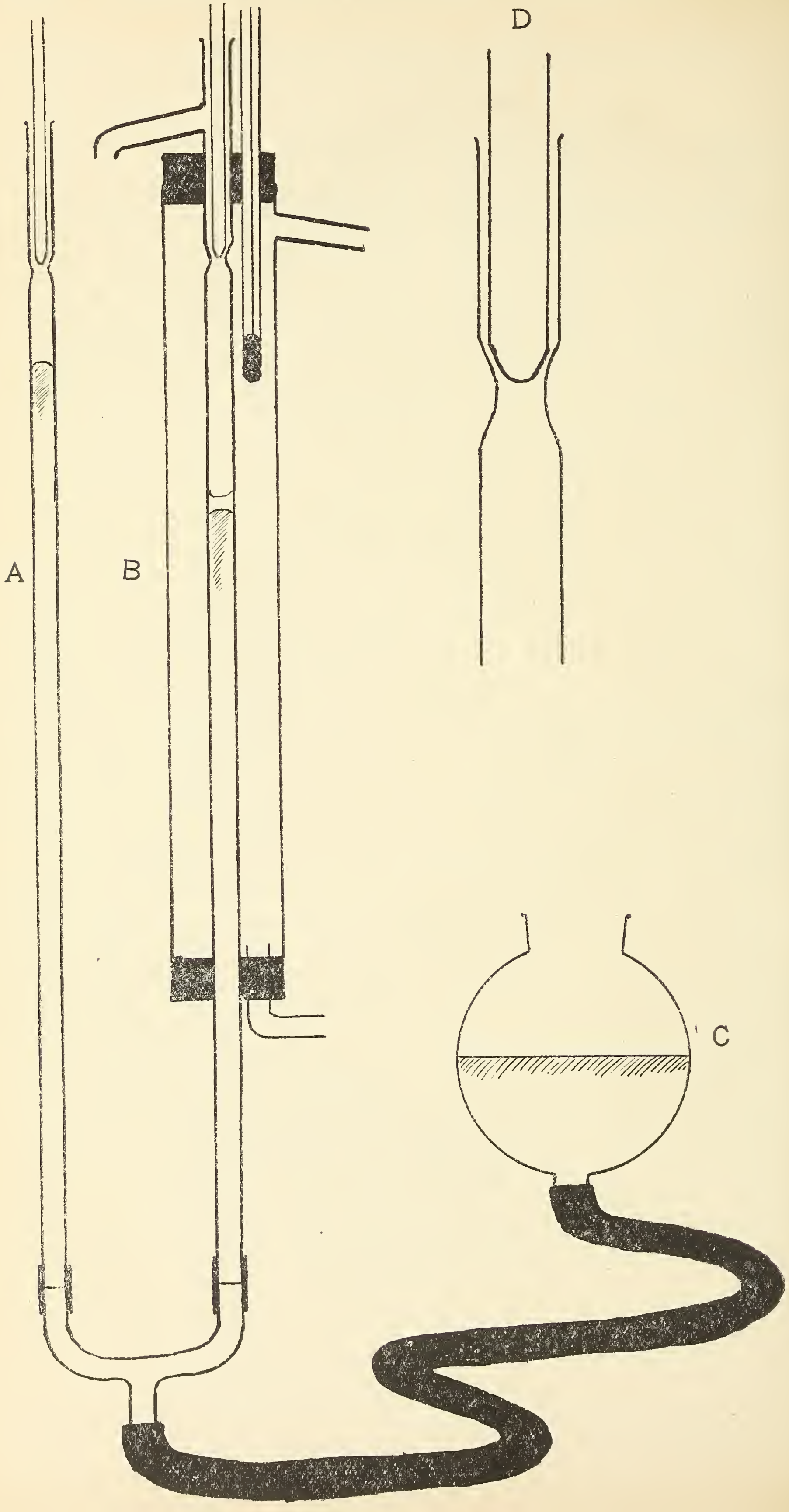

Finish
98.5% at 233°C
Residue 1.5%
Final Distillation
Residue 5.55%
Loss 14.8%
Residue 8.35%
Loss 2.9%
ENGLER DISTILLATION
DISTILLATION 1
" 2
" 3
" 4
Degrees Centigrade
% Distilled
100
110
120
130
140
150
160
170
180
190
200
210
220
0
10
20
30
40
50
60
70
80
90
100

Figure 2.—Vapour Pressures of Fractional Distillates of Roma Oil, 27th February, 1928.




D
A
B
C

The Brisbane Tuff.

By Mrs. C. BRIGGS.

Plates VIII. and IX.

(*Communicated to the Royal Society of Queensland by Dr. W. H. Bryan, 29th October, 1928.*)

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I.—INTRODUCTION AND PREVIOUS LITERATURE.

The Brisbane Tuff is the name given to the rock, composed mainly of pyroclastic material, which occurs at the base of the Ipswich Series of Upper Triassic age in and around Brisbane.

Several references have been made to it by earlier workers, but the majority of these do not describe it in any detail but merely note its existence.

The earliest reference to what we now know as the Brisbane Tuff was made by J. S. Wilson[1] in 1856 in his " Notes on the Geology of the Neighbourhood of Sydney, Newcastle and Brisbane " in which he wrote: " Traversing the town of Brisbane, there is a large dyke [*sic*] of flesh-coloured porphyry, containing crystals of quartz and felspar and many fragments of the slate rock through which it has been erupted. These fragments show no indication of having been fused or altered. The dyke is 200 ft. thick; it rises up between the slates and is parallel to them in direction and dip."

W. H. Rands,[2] in 1887, in his report accompanying the geological map of the city of Brisbane and environment, referred to the occurrence of a rock running north and south through Brisbane. This, as we have seen, had formerly been regarded as a porphyry, but Rands after a study of its megascopic characters definitely classed it as a volcanic ash. He also referred to its stratigraphical position at the base of the Ipswich Measures and to its use as a building stone.

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[1] Q.J.G.S., vol. xii., 1856, p. 288.

[2] Rands's Report accompanying the Geological Map of Brisbane. Geol. Surv. Qld. Publ. No. 34, 1887, p.1.

In 1888 Dr. R. L. Jack,[3] in his paper "On Some Salient Points in the Geology of Queensland," notes the outcrop of a series of "ashy sandstones" at the base of the Ipswich Coal Measures containing carbonised and silicified wood, to be seen in Brisbane resting unconformably on the Brisbane Schists. The same writer[4] in 1892 added that at Ann street, Brisbane, the rock dips at 18 deg. and is separated by 31 in. of light and dark coloured shale from the older micaceous schists which the shales overlie unconformably.

Dr. E. O. Marks in 1911[5] published a paper on the "Coal Measures of South-east Moreton." In this he stated that a bore was put down at Mona Park through 27½ ft. of tuff, and was overlain by shale at a depth of 470 ft. He stated further that "the occurrence of volcanic tuff in the bore at Mona Park is thus of more than mere geological interest, for tuff is known to be at the base or near the base of the Coal Measures and it now seems probable that it extends beneath the system over the whole area between Logan Village and Brisbane." "The Coal Measures of the Broadwater, Tingalpa area, and of the coastal area of South-east Moreton are generally associated with tuff." Accompanying Marks's report is the most recent geological map of Brisbane.

In his paper on the Volcanic Rocks of South-eastern Queensland Professor Richards[6] gave a concise petrological description of the Brisbane Tuff.

Dr. A. B. Walkom, in 1918,[7] in his "Geology of the Lower Mesozoic Rocks of Queensland," referred to the Brisbane Tuff as "a rock probably of volcanic origin although there is no indication of its source, resulting from the deposition of volcanic ash of an acid nature over a long narrow area in the vicinity of Brisbane."

The most detailed description of the Brisbane Tuff is to be found in Professor H. C. Richards's[8] paper on "The Building Stones of Queensland," published in 1918, which deals briefly with its megascopic and microscopic characters, and at considerable length with its value as a building stone.

Mr. B. Dunstan, in 1920,[9] in an introduction to Sahni's paper on "Petrified Plant Remains of the Queensland Mesozoic and Tertiary Formations, gave a short account of the stratigraphical position of the tuff, and remarked on the great abundance of the petrified woods and the position which they occupy relative to the tuff.

Mr. C. C. Morton, in 1922,[10] in an article on "The Coal Prospects of the Narangba District," noted that in Portion 30 of the Parish of Whiteside

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[3] "On Some Salient Points in the Geology of Queensland," p. 8.

[4] "Geology and Palæontology of Queensland and New Guinea," by Jack and Etheridge, p. 321.

[5] "Coal Measures of South-east Moreton," Qld. Geol. Surv. Pub. No. 225, p. 15

[6] P.R.S.Q. 1916, p. 145.

[7] Proc. Linn. Soc. N.S.W. 1918, p. 48.

[8] P.R.S.Q. 1918, p. 137.

[9] Geol. Surv. Qld. Publ. No. 267, p. 1.

[10] Qld. Govt. Mining Jour. May 1922, p. 4.

there is an extensive exposure of the rhyolite agglomerate and tuff which thereabouts forms the base of the Coal Measures and is probably the equivalent of the Brisbane Tuff.

Mr. O. A. Jones,[11] in the appendix to his paper on "The Tertiary Deposits of the Moreton District," has described a volcanic tuff which in thin section closely resembles the Brisbane Tuff, although in the hand specimen the rock resembles that found in the Chermside and Aspley districts more closely than the typical rock found nearer to Brisbane itself.

This tuff, which outcrops at Mount Crosby, is only about 4 ft. thick and grades into a compact tuffaceous shale, but it appears to occupy the same position relative to the Ipswich beds as the tuff does in Brisbane.

In 1927 Professor H. C. Richards and Dr. W. H. Bryan published a paper on "Volcanic Mud Balls from the Brisbane Tuff."[12] The outcrop described was at Castra, on the right bank of Tingalpa Creek, about 12 miles E.S.E. of Brisbane. Since the publication of this paper several specimens very similar to those obtained from this outcrop have been found at Aspley.

II.—FIELD OCCURRENCE.

The Brisbane Tuff, as previously stated, outcrops within the city of Brisbane itself, and most of the previous references include results which have been based on a study of these outcrops, that at the intersection of Ann and Gotha streets in particular having attracted the attention of several geologists.

It was not until Marks connected up the isolated outcrops in 1911 that the extent of the series was indicated. His map shows that with one exception all the outcrops are confined within an area of 80 square miles. Since then the tuff has been found in several other localities.

The main outcrop extends for about 15 miles in a direction N. 30° W. It has been traced continuously in a northerly direction as far as Aspley, where its boundary becomes indefinite owing to the presence of overlying alluvial material. Further north it occurs as a few isolated outcrops, the most northerly of which is at Narangba, which is 4 miles from Aspley. Passing southward through Brisbane the main outcrop bifurcates, the southern limit of the western leg being at St. Lucia and that of the eastern at Coorparoo.

The width of outcrop is at its greatest about ¾ mile, but is throughout most of its length considerably less than this. In the vicinity of its greatest width, the greatest vertical section (about 100 ft.) is exposed. But this is not a maximum thickness, for the base in most cases is not shown. Thus the cliffs at Kangaroo Point, composed wholly of tuff, are about 100 ft. high, but the line of junction with the Brisbane Schist is out of sight and below the level of the Brisbane River. Above Collin's wharves and at Leichhardt street and in several of the quarries good vertical sections of

[11] Proc. Roy. Soc. Qld. 1926, p. 43.

[12] Proc. Roy. Soc. Qld. 1927, p. 54.

the material can be seen, but except in a few cases, as at Campbell's Quarry (Albion), Boggo road, Belmont, and Gotha street, the junction is not above the surface. In a few localities the dip and width of outcrop are known and the thickness may be calculated. For instance, at Belmont the width of outcrop on either side of an anticline can be seen and this gives a total thickness of about 300 ft. At Boggo road the thickness has been determined as approximately 160 ft.

In the main outcrop there are one or two sections which show clearly the relationship which exists between the tuff and the associated beds. A vertical section at Ann street[13] showed the following conformable succession from the bottom :—

(1) A few feet of carbonaceous shale ;
(2) A hardened band of tuffaceous material about 1 ft. 6 in. in thickness ;
(3) The main mass of the tuff about 15 ft. in thickness covered by a thin layer of soil, the whole resting unconformably on the Brisbane Schist.

Near the Children's Hospital is to be seen a similar section to that at Ann street, differing from it only by the presence of a conglomerate in place of the basal shales.

Walking across the beds on Boggo road the following succession is passed over :—

(1) Brisbane Schist ;
(2) A few feet of shale containing fossil wood ;
(3) True tuff, which is here highly silicified ;
(4) A series of very striking conglomerates containing huge boulders of quartzite ;
(5) Tuffaceous sandstones and shales.

This occurrence of fossil wood between the Brisbane Schists and the shales is very characteristic and, as Mr. Dunstan pointed out, serves as an indication of proximity to the junction line between the Brisbane Schist and the Brisbane Tuff. When present, the conglomerate mentioned above serves a similar purpose for the determination of the upper limit. Unfortunately this is not always present and the lithological change is often so gradual that it is very difficult to make any line of demarcation as to the upper limit of the tuff.

A small section which shows how the tuff may thin out between the Brisbane Schist and the Ipswich Coal Measures is to be seen in Campbell's Quarry at Albion. Here the schist forms the base. Above this are a few feet of very much altered tuff, and resting on this again are the Ipswich Measures. Nowhere is the dip of the tuff very steep, this being an indication that very little movement has taken place since the material was laid down. The maximum dip so far determined is about 20°. Although the tuff is

[13] This section is no longer exposed.

conformable with the shales below and above it, and was probably laid down under similar conditions, it shows little evidence of stratification.

Although the above remarks refer to the main outcrop only, they are generally applicable to the whole area. An outcrop which may be regarded as a continuation of the main mass occurs at Tarrigindi. Its exact extent is difficult to determine owing to the presence of alluvial material which covers a considerable portion of the area. Of the other outcrops that which runs through Belmont in a direction similar to that of the main mass is the largest. The material found here is similar to the white tuff found at Collin's wharves. About a mile to the east of Belmont are two outcrops with their greatest length in a direction at right angles to the two main outcrops. About 9 miles to the south of these and in a direct line with them is a very small area of tuff at Loganlea. Although there is no tuff on the surface between the latter and former outcrops, it is quite likely that it occurs below the ground-level over quite a large part of the area. Bores have been put down at Mona Park and tuff has been found between the Brisbane Schist and the Ipswich Measures at a depth of over 400 ft. A further small isolated outcrop occurs at Castra. Near Morningside there is a small outcrop of the characteristic tuffaceous material in the nature of an inlier within the Ipswich Measures. In the railway cutting a few yards from the quarry a definite junction between the Brisbane Schist and the Ipswich Coal Measures can be seen, the tuff being present only in the form of boulders in the conglomerate. The thickness of the tuff here is evidently not very great, as the quarrymen report having found shales at no great depth below the present road-level.

To the south of this there is an outcrop near White's Hill. The material here is not as characteristic as that at Morningside, and its exact extent is not determinable.

III.—PETROLOGICAL CHARACTERS.

(A) Megascopic Characters.

The Brisbane Tuff is a truly fragmental rock, being composed of tuffaceous material of an acidic nature with included rock fragments.

(a) *Arrangement and Nature of Inclusions.*

There does not appear to be a persistent regularity in the arrangement of inclusions. In some cases there is no definite arrangement, while in others there is a distinct tendency towards parallelism. The latter is often exhibited by the soft, powdery spots which occur in the pink variety, reference to which will be made later. A linear arrangement of small drusy cavities into which small quartz crystals have grown is noticed in some of the material from Bowser and Lever's quarry at O'Conneltown. These represent replaced fragments of schist.

Fragments of igneous rock can sometimes be seen in the hand specimen, but it is often difficult to determine whether this material is really a foreign inclusion or part of the original igneous mass. Those inclusions which are seen are of an acid nature, quartz and felspar being the only determinable minerals. These have the same characteristics as those in the ground-mass, but the felspar is sometimes more weathered.

One or two specimens show inclusions of a dark-green rock which is apparently igneous in nature, and in which decomposed felspars are abundant.

The fragments of schist owing to their dark colour and typical cleavage are easily distinguished. They generally resemble the local schist very closely and usually show no evidence of being waterworn. In some cases they have been altered subsequent to inclusion to a sericitic mass, and as indicated above have sometimes been replaced by silica. The slate inclusion from Morningside may be a variant of the schist, and like the schist no minerals can be distinguished. The inclusions vary largely in size, although in the city itself they are remarkably small and of fairly even size. At Morningside they are much larger, the greatest being about 5 in. square, and at Bowser and Lever's quarry at O'Conneltown some fragments approximate to this size. A very common inclusion is that of small fragments of chert which as a rule measure only approximately $\frac{1}{4}$ in. in diameter. Occasionally larger fragments are found at Windsor, where the largest seen was about 5 in. in diameter.

Minerals Present—

These may be considered under two headings—

(1) Those which can be determined in the fragments ;

(2) Those which belong to the ashy material.

In dealing with the former a short account of the nature of the inclusions themselves will be given.

As the rock is composed mainly of ashy material one would not expect to find many minerals in crystalline form, the only recognisable individual minerals being quartz and felspar.

Quartz.—This is generally in the form of blebs which never exceed $\frac{1}{10}$ in. in diameter, and are characterised by their translucency and freshness.

Felspar.—The felspar on the other hand generally occurs in elongate crystals, white in colour, opaque and very often much altered to a pale-green decomposition product and kaolin.

The presence of iron is indicated only by limonite stainings most probably of foreign origin.

(*b*) *Bedding and Stratification.*

The most characteristic feature of the tuff is its uniformity and lack of bedding. The compact character of the series as a whole seems to have been induced for the most part by the deposition of siliceous material from percolating solutions, which may have had the same origin as the tuffaceous material itself. The general uniformity of silicification does not suggest injection but rather downward percolation of such solutions. There seems to be an increase in silicification as we pass northward from Brisbane, but no such generalisation can be made regarding any other part of the outcrop.

In some cases, as at Leichhardt street, silicification has increased with depth. Here may be mentioned a more highly siliceous and compact band of material varying from about 2 ft. to a few inches in thickness, lying at the very base of the tuff. This band is sharply differentiated from the rest of the tuff, so much so that it has been thought by some to represent not a tuff but a rhyolite flow. It differs further from the material above in not containing fragments of schist, fossil remains, or carbonaceous material in any quantity. Its occurrence as a thin sheet fairly uniform in thickness does suggest a rhyolite flow, but on the other hand the absence of fluxion structure and the marked similarity in microscopic structure to the overlying material suggests that it is truly tuffaceous material which has become hardened by the percolation of siliceous solutions.

Professor Richards[14] in speaking of this particular band says: "It is noticeable however that this band is best developed when the overlying tuff is most silicified and it is highly probable that it represents a layer of tuff at the bottom which has received an extra amount of silicification owing to the percolating solutions being held up by the impervious underlying shale band." In some cases small bands of this silicified material give an appearance of stratification, but these are probably veins or cracks which have been filled up with the siliceous material or parts of the rock in which replacement has taken place.

Again, it has been noted in a few instances that in the upper levels of the tuff a banding is induced by weathering. The marked character and regularity of this, particularly in one specimen, gives the rock a stratified appearance. This was found at Kangaroo Point, although probably not *in situ*, as it differs considerably from the typical rock of this locality. The bands, which are roughly parallel, vary in width from $\frac{1}{10}$ in. to 2 in. and in colour from pale mauve to deep purple.

Colour.—There is great variety in colour, although perhaps pink is predominant; white, grey, green, brown, and all shades of purple also occur, the colour varying with the amount of iron and manganese oxides present and their state of oxidation. No one variety is confined necessarily to any one area, for in most cases we find two or more colours in close proximity to one another. The colour is generally evenly distributed throughout the specimen itself, except in the case where limonite stainings are present.

The colour of the rock is of great importance, since it serves as an indication of its weathering properties. The pink and white varieties appear to be the most stable, but some of the pink material has a series of soft white powdery spots, the larger of which seem to have a tendency towards parallelism. These may represent weathered inclusions, but their outline seems in most cases to be rather indefinite, and in no case has a transition stage between an inclusion and the powdery material been observed.

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[14] Proc. Roy. Soc. Qld. 1916, p. 146.

Further, small siliceous particles resembling those of the main mass are generally found in the powder. It seems more likely that these patches are the result of differential weathering of the tuff itself. The more silicified material is generally white and more stable on account of its low iron percentage. As the silicification has been rather irregular, such white tuff is somewhat confined in different areas. The grey tuff is limited to the highly siliceous band at the base of the series.

Brown colouring, except as a surface coating, is found only in very weathered material. The green tuffs as a rule weather badly, the paler green varieties decomposing into a whitish shaly material which slakes easily. On the darker green varieties a dark coating forms which seems to protect them from further decomposition. This may be seen in progress in the O'Conneltown and Windsor quarries, particularly in the former.

(b) *Microscopic Characters.*

After the microscopic examination of slides from various localities one is struck by the uniformity of the tuff in texture and composition. With the exception perhaps of the material from Boggo road, and the lower siliceous band, the sections differ very little. The following description is given as the result of the study of some twenty-four slides made from rock taken from the more important outcrops. The typical tuff is seen to be composed of a light-brown base which generally appears very much altered and is for the most part isotropic. In this are set crystals of quartz and felspar, and inclusions of foreign rock material the character of which can generally be determined.

The original glassy structure can often be seen, and is particularly well developed in some of the sections of material taken from Bowser and Lever's quarry at Morningside. This warrants Pirsson's name " Vitric Tuff " being applied to this rock. Some of the inclusions show a linear arrangement.

The structures within the inclusions are not always easy to detect. The schistose structure so easily seen in the hand specimen cannot be determined under the microscope. In some of the igneous rocks a structure resembling microperthic is developed. As the character of the quartz and felspar in both the base and the inclusions appear to be the same, a detailed description of them will be given when discussing the fragments of igneous rocks. There is a complete absence of ferro-magnesian minerals, the presence of iron being indicated only by limonite staining, which in some cases may be derived from a foreign source.

Schists.—These are only very small and the only basis for terming the majority of the schists is their shape and colour. They are generally dark in colour and more or less elongate.

Cherts, Quartzite, etc.—Some of the sections show numerous black, opaque fragments which may possibly be charcoal, but more probably represent foreign rock material such as cherts, quartzites, etc.

Igneous Rock—

These are abundant, and seem to consist of quartz and felspar which are sometimes set in a glassy base.

Quartz.—This is generally very fresh, often with numerous inclusions of felspar, other minerals too small to be distinguished, and air bubbles. The crystals are often very much corroded. Except where corrosion has taken place the outline is sharp, most of the fragments being triangular in shape. These fragments vary in size but the largest does not measure more than one millimetre across. A striking feature of the quartz is the absence of cracks.

Felspar.—There are at least two varieties of felspar present.

Orthoclase occurs in roughly rectangular crystals generally with one well-developed cleavage and always highly decomposed, alteration taking place along the cleavage lines. This often gives the effect of intergrowth when the section is placed between crossed nicols. The alteration seems to be mostly to kaolin, there being no trace whatever of secondary mica in any of the slides. A characteristic of this felspar is the comparative absence of twinning. This may be only apparent, as the twinning could be easily masked by alteration. Some of the fresher crystals show simple twinning.

Very few inclusions are seen, but these again may be easily masked by alteration. Micrographic intergrowth of quartz and felspar occur, a very good example of which is seen in a section taken from Morningside. There does not appear to be any orientation arrangement of the long axes of the crystals. There is present in much smaller quantities a felspar showing multiple twinning, which has an extinction angle, corresponding to that of *Andesine.* One or two felspars seem to show a continuation of Albite and Pericline twinning, but as the crystals themselves are so small and the twinning itself is on such a small scale it is difficult to state whether this is microcline or one of the Plagioclase series. These felspars, too, show various degrees of alteration. There are no other distinguishable minerals present in these inclusions, and the complete absence of ferro-magnesian minerals suggests that the rock is derived from material of a very acidic nature.

The rock is commonly known as "porphyry" and has at different times been referred to as an "ashy sandstone," "trachytic tuff," and latterly as a "rhyolitic tuff." Its pyroclastic nature was recognised by W. H. Rands as early as 1887.

The chemical analysis as determined by Mr. G. R. Patten, of the Agricultural Chemists' Laboratory, shows that the rock is decidedly acid in nature and most closely resembles some of the Tertiary Rhyolites of South-eastern Queensland.

In the light of a combined megascopic and microscopic study, the rock then merits the name "Rhyolitic Tuff."

IV.—CHEMICAL CHARACTERS.

Comparison of Analysis of Brisbane Tuff (1–3) with other Local Igneous Rocks (4–8) and with the World's Average Rhyolite (9).

—	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
SiO_2 ..	75·52	..	..	73·52	71·50	61·10	77·15	74·28	72·62
Al_2O_3 ..	12·73	..	..	11·05	14·13	19·24	13·45	11·27	13·77
Fe_2O_3 ..	2·18	..	..	Nil	0·60	1·24	0·40	1·93	1·29
FeO ..	1·43	..	..	3·15	3·23	3·42	1·26	0·58	0·90
MgO ..	0·27	..	..	1·03	1·17	2·56	0·72	0·44	0·38
CaO ..	0·28	..	..	1·70	2·70	5·25	1·22	1·15	1·43
Na_2O ..	2·30	0·76	0·34	4·08	2·97	3·82	2·72	2·74	3·55
K_2O ..	3·47	1·85	2·68	3·99	2·86	1·68	3·76	4·77	4·09
H_2O ..	1·20	..	..	0·44	0·32	1·31	0·20	1·01	1·53
H_2O ..	0·48	..	..	0·16	0·10	0·64	0·08	0·70	..
TiO_2 ..	0·30	..	..	0·20	0·41	..	..	0·25	..
P_2O_5 ..	0·16	..	..	0·15	0·35	..	0·10	0·07	..
MnO ..	0·01	..	..	..	tr.	..	0·32	0·02	0·12
	100·57	..	..	99·47	100·36	100·26	101·38	99·21	99·68

(1) Brisbane Tuff, Bowser and Lever's Quarry.
(2) Alkali content of Tuff obtained from Collin's Wharves.
(3) Alkali content of hard band of Tuff at base of cliff at Collin's Wharves.
(4) Typical Pink-phase Enoggera Granite.
(5) Enoggera Building Stone.
(6) Typical Grey-phase Enoggera Granite.
(7) Granite, Stanthorpe.
(8) Rhyolite, Esk.
(9) Average Rhyolite, Daly.

The first three analyses were carried out by Mr. Patten, of the Queensland Agricultural Chemists' Laboratory. The others have been added to the list for the purposes of comparison.

The analysis of the Brisbane Tuff shows a very high silica percentage, thus the rock is distinctly acid in nature. The iron percentage is exceptionally high for an acid rock, but part of this has probably been derived from the foreign material present. The variation in the alkali content, as shown by the three analyses made, is very striking. The tuff from which the analysis was made at Collin's wharf is decidedly more siliceous than the average material, but that would not altogether account for the extremely low alkali content.

Except that they all have a high silica percentage, they do not resemble the analyses of the granites from Enoggera very closely, but they may better be compared with that from Stanthorpe. Here the alkali contents more closely correspond, and while the iron is higher in the tuff the silica is slightly higher in the granite.

Analyses of rhyolite from Esk and of the average rhyolite composition as determined by Daly show that the rock resembles these more closely than the granites of the Brisbane district.

V.—INCLUDED PLANT REMAINS.

Fossil wood is very plentiful in the shales immediately below the tuff, but it seems that there is not a great abundance actually included in the tuff.

(1) At Morningside an equisetaceous stem fragment about 9 in. long showing eight nodes and seven complete internodes was found. The internodes vary in length from ·7 in. to 1·2 in. Some of the wood has been preserved, but after exposure to the air this is rapidly decomposing to form a brown powder, and therefore cannot be easily handled. Where striations can be seen they appear to be continuous through at least two adjacent nodes. On account of its fragmental nature an exact determination of the genus cannot be made. It certainly belongs to the family of Equisetales, and may be *Phyllotheca* or *Schizoneura*, the latter of which is more commonly found in the Lower Mesozoic strata of Queensland.

This fossil, which has been exhibited at a previous meeting of the Royal Society, is preserved in a highly silicified tuff.

(2) At the Windsor Council quarry there has been unearthed a charred tree-trunk. This material shows the typical wood structure, particularly on heating in the air, when it turns white.

In the University of Queensland Geological Museum there are specimens showing fragments of charcoal and silicified wood actually included in the tuff.

In several cases wood has been found in close proximity to weathered tuff, and it seems quite likely that in some instances such has originally been included in the tuff. Such fossil woods as are found *in situ* occur near the base. Those tree trunks and limbs which have been found both in the tuff and underlying shales seem to lie with their long axes approximately horizontal.

Sahni described and named several fossil woods sent to him from South-eastern Queensland, but the only one of these belonging to the Triassic is *Cedroxylon brisbanense*, which was found near Boggo road. The detailed description of this may be seen in Sahni's paper already cited.

VI.—AGE AND ORIGIN.

Age of the Tuff.

The conformity which exists everywhere between the Brisbane Tuff and the Ipswich Series indicates that there has been practically no time-break between their deposition.

There are many sections which show this relationship between the tuff and the rocks below it, but that at Ann street is worthy of special mention.

The fossil evidence is not sufficient to assist in the exact determination of the age of the Brisbane Tuff, and the field evidence thus indicates that the material which formed the tuff was extruded not later than late Triassic and not earlier than earlier Triassic times.

Origin.

That the material is of a volcanic nature has already been established. The problem of origin and mode of deposition, however, is one not easily solved, evidence being rather insufficient and in some instances confusing. Nevertheless, there are a few significant facts which may assist in the final solution of the problem.

(1) There is a marked uniformity in the size of the inclusions and in the nature of the ash itself. The former are generally small, the only localities where fragments over ½ inch in length have been found being at Morningside, Windsor, and O'Conneltown, where the largest was only 5 in. square. These larger inclusions occur near the base of the tuff. It is significant that where the lower more siliceous band occurs it is particularly free from inclusions of schist, although slaty, cherty, and rhyolitic fragments are fairly common. These, however, are small and generally rounded or subangular.

(2) Mr. Dunstan[15] states that "volcanic outbursts at the beginning of the Triassic formed a very thick deposit of dust and ash over the valleys and hills of the Brisbane district, and the timbers growing on the shale and the schists at that time were enveloped and destroyed by a great thickness of this dust. The deposits were evidently not laid down as mud, as the tops of the hills were as thickly covered as the bottoms of the valleys, while in addition fragments of charcoal at the base of the tuffs, quite unchanged even after such a length of time, give evidence of the burning of some of the timber while its envelopment was taking place. The exterior portion of the trunks of the trees which have been charred by fire have not been fossilised, but, where the wood has not been burnt and evidently covered over while green, the hot percolating waters carrying in solution silica derived from the minerals in the volcanic ejectamenta have subsequently silicified the cells of the wood."

It may be significant that charcoal and fossil woods do not occur in the lower more highly silicified band of rock, and that where they do occur in the main mass of the rock the lower band is conspicuously absent.

(3) The shape and direction of the outcrops might lead one to suppose that the tuff was laid down in what constituted the valleys of Triassic time. If the suggestion of E. O. Marks, that the tuff had practically the same distribution as the Ipswich Measures in this area, is correct, the shape of the outcrop would be of no significance. Evidence from the bores which have been put down tend to support the suggestion, but these lie on the same line as the main outcrop, so that such evidence is not conclusive.

There is no direct indication of the centre of eruption of this tuffaceous material within a reasonable distance of its outcrops. The uniformity of the material suggests that the source of origin was approximately at the same distance from all points on the outcrops. This, together with the fineness of the material and the absence of coarse volcanic ejectamenta, would suggest that the source was not very close to the present outcrops. Certainly the material was not transported any distance by water, for the included fragments are angular, there being a conspicuous absence of rounded pebbles in the main mass of the material. At the same time some

[15] Introduction to Sahni's paper, Geol. Surv. Qld. Publ. No. 267, p. 5.

of the cherty and rhyolitic inclusions found in the more highly silicified "lower band" are distinctly rounded and subangular.

We know that in Triassic times there was an extension of the present land mass to the east, and as there is no trace of a centre on the land at the present it might be assumed that the centre is now below sea-level.

The association of the "lower band" with the underlying shales favours the suggestion that it was laid down under water. The absence of large fragments and the rounded character of the cherty rhyolitic inclusions is also in favour of such a suggestion.

It has been stressed above that charcoal or fossil wood in the tuff is not particularly abundant, and that its occurrence is rather local. The presence of fossil wood in quantity in the underlying shale is evidence of a heavily wooded land surface. If the tuff were deposited wholly on such a surface it seems that fossil wood or charcoal would be much more abundant than it actually is, and that there would be much more evidence of fossilisation and charring *in situ* than is obvious. Most of the charred wood actually in the tuff is fragmental, and where trunks or limbs occur these are always in a prone position.

From the evidence it seems that the tuff was laid down on land surface, the continuity of which was broken by a series of small freshwater lakes. These may have represented the youthful stage of the lake system in which the Ipswich Measures were subsequently deposited. In them possibly the more highly silicified tuff was deposited contemporaneously with that deposited on the land surface, and that the silica-charged water subsequently caused the extra silicification.

VII.—RELATIONSHIP TO OTHER IGNEOUS ROCKS.

In general there seems to have been a dearth of volcanic activity during the Triassic period, but the late Palæozoic era was characterised by worldwide movements and intrusions on a very large scale, which latter are represented in South-eastern Queensland by the granitic masses at Stanthorpe and Enoggera, etc. Subsequent to these were intruded a series of dykes which may be seen in and around Brisbane, especially in the immediate vicinity of the Enoggera mass. The Stanthorpe and Enoggera masses were intruded probably at the close of the Palæozoic or at the latest in the early Mesozoic era, and were followed by the deposition of a series of volcanic tuffs probably in late Triassic times. Is there any genetic relationship between the Brisbane Tuff and the earlier intrusions ?

For some years there has been a general belief that there may be some such connection. Thus[16] Mr. L. C. Ball, in his "Notes on Indooroopilly," stated that "if the Brisbane Trachytic tuff could be connected with the dyke at Indooroopilly we might be in a position to decide on the period in which deposition took place, but the necessary petrological work has not yet been done."

The facts that no source of the tuff can be found, that the granite, rhyolitic dykes, and tuff are similar in chemical composition in that they

[16] Qld. Govt. Min. Jrnl. 1920, p. 266.

are all acid and that they occur in somewhat close proximity to one another, would lead one to seek a connection between them. Inclusions of rhyolitic material very similar to that of the dykes are found in the tuff, but there is no trace of any fragments of the granitic series.

Some of the aplitic dyke material resembles the more highly silicified tuff very closely in appearance. When examined under the microscope the rhyolitic inclusions resemble very closely the true dyke material; although the actual felspars present in the latter have not yet been determined.

It is interesting to note that andesine is the only plagioclase felspar which has been determined in the tuff, and Dr. Bryan states that andesine is very plentiful in the grey phase (hybrid rock) of the Enoggera Granite series.

A consideration of all the evidence points to the following chronological order of the rocks in the Brisbane district :—

Upper Triassic ..	Lacustrine Deposits	Coal Measures
	Pyroclastic Sediments	Tuff
	Lacustrine Deposits	Shales and Conglomerates.
Late Palæozoic ..	Hypabyssal Intrusions	Porphyritic Series
		Rhyolitic Series
	Plutonic Intrusions	Enoggera Granite.

It has been proved that there are generally three distinct phases of igneous action, their respective characteristics being (1) volcanic extrusions followed by (2) large plutonic intrusions, which in turn are followed by (3) minor intrusions. But Harker[17] points out that " there has been in several past periods a final reversion to the extrusive phase of action following what we have regarded as the normal cycle of earth movements and divided from it by a considerable interval of time. This recrudescence of vulcanicity has always been relatively feeble and has operated within a much restricted area or broken out in a few isolated centres." In South-east Queensland these phases may all be recognised, but the earliest extrusive phase (which may be represented by the volcanic Permo-Carboniferous rocks of the Silverwood district) is absent in the Brisbane area. The above chronological table shows the Enoggera granite, representing the large intrusive phases and the dykes of porphyritic and rhyolitic material, as the representative of the third phase. Separated from these by a considerable space of time there is the Brisbane Tuff, which may perhaps be regarded as the result of this later smaller phase of volcanic action.

Professor Sir Edgeworth David says: " In New South Wales there is a considerable development of more or less fine volcanic tuff in the lower division of the Triassic known as the Narabeen stage. These tuffs are distinctly basic in character and like the lava of the Permo-Carboniferous contain metallic copper. Through redistribution in water the tuffs have passed into the characteristic chocolate shales so well known at Long Reef

[17] Harker, " Natural History of Igneous Rocks."

and Narabeen." But these rocks are very different in character from the Brisbane Tuff. Indeed, the Brisbane Tuff resembles more closely in both megascopic and microscopic characters some of the Tertiary volcanic ashes.

Since volcanic activity in Triassic times throughout the world was comparatively rare, the Brisbane Tuff attains an added interest and importance.

VIII.—ECONOMIC VALUE.

It was not long before the residents of Brisbane realised the economic value of the Brisbane Tuff, commonly known to them as porphyry, for as early as 1855 it was used in the building now known as Rosemount Hospital. Since that time it has been used locally on an extensive scale for building stone and other purposes. As has been stated previously, the rock varies greatly even within very restricted areas, the specific gravity ranging from 1·92 to 2·27 and absorption from 4·25 to 11·75 per cent. The tuff although not always well jointed is not difficult to work. Apart from its use as a building stone it has been used for kerbstones, road metal, and the finer material for footpath and tennis-court dressings.

Dr. H. C. Richards in the "Building Stones of Queensland" deals fully[18] with the value of this rock for building purposes. As a building stone the tuff may be used to advantage, provided it is carefully selected, and not placed in a position where it is subjected to the continuous action of moisture or to great pressure.

The more compact and silicified the tuff, other factors being equal, the better it is as a building stone. Most of this material, which is used in the buildings of Brisbane, comes from the quarries at O'Conneltown and at Leichhardt street. It has been silicified to a moderate extent, and the inclusions which give the tuff at Kangaroo Point such a weathered appearance are practically absent in the stone at O'Conneltown. As in most building stones, the undressed stone weathers better than the dressed material.

The great advantage of the rock for all the purposes mentioned above is its easy accessibility and consequent low cost, none of the quarries being more than a few miles distant from the city.

List of Buildings where the Tuff has been used.

Rosemount Hospital (1855).
Normal School (1863) ; Spring Hill.
Base of the G.P.O. (1871-1874).
St. Stephen's Cathedral (1874).
St. Paul's Presbyterian Church (1887) ; Spring Hill and O'Conneltown.
St. John's Cathedral (1909-1911) ; O'Conneltown.
Base of the Government Printing Office, 1912.
Police Commissioner's Office.
First three courses of Roma-street Railway Station.
Base of the Treasury Building.

[18] Proc. Roy. Soc. Qld., xxx., pp. 137-140.

Abutments of Victoria Bridge.
St. Mary's Church, Kangaroo Point.
Parts of the University.
Gregory-terrace School.
Numerous Retaining Walls.
The Holy Name Cathedral.

Reports on Quarries.

Bowser and Lever's Quarry.

This is the largest of the quarries and is situated opposite Rosemount Hospital at O'Conneltown. A cliff about 60 ft. high is being worked and the base of the tuff has not yet been reached. It is from this quarry that most of the material of recent years for building stones has come. Here the tuff varies from pale pink to dark purple in colour, and all the material with the exception of a small quantity of the dark and pale-green varieties is good. The dark-green material does not weather as badly as the pale-green and may be used as a road metal.

The best of the material is used for building stones, kerbstones, and water plates, and then by means of a grader the rest after crushing is sorted and used for road metal, footpath dressings, and tennis-court dressings.

Windsor Quarry.

This is much smaller than Bowser and Lever's quarry, and the material owing to weathering is not so good. It is situated in a loop which occurs in the outcrop of the tuff near the old Windsor Shire Council office. Jointing is very irregular. Work has now ceased in this quarry.

Exhibition Quarry.

This is not being worked at the present time, but a good deal of rock has been previously obtained here, where a cliff about 40 ft. high is to be seen.

Leichhardt Street.

This quarry, although not being worked now, has been the source of supply of a quantity of stone which has been used in the buildings of Brisbane as road metal and for other purposes. It was one of the earliest to be opened. The material here shows great variety in quality, and at the base the hard silicified band so well seen at the junction of Ann and Gotha streets also occurs.

Kangaroo Point.

At Kangaroo Point a cliff about 100 ft. high is to be seen. The great disadvantage of the rock here is the presence of elongated inclusions of a whitish material which decomposes very rapidly. It is now used only as occasion demands for road metalling, etc.

Brisbane Wharves Ltd.

The rock here is rather fine-grained, compact, and free from inclusions. It is nearly white in colour and it has the disadvantage characteristic of all the white varieties in that it grows moss easily. The material is mostly used for road metalling.

Morningside.

This is only a small quarry, and was formerly partly owned by the Bulimba Town Council and partly by that of Coorparoo. That owned by Bulimba has the better material, which is fairly highly silicified and mostly pink in colour. The material owned by Coorproo is in some parts very much altered. The size of the inclusions in the rock here are a distinct disadvantage, since it causes it to disintegrate more easily. The material is used for road-making, etc.

St. Lucia.

This material is white in colour, relatively free from iron staining, and is used locally as a road metal. The quarry is not large but a face about 20 ft. high is at present being worked. These are the only points of outcrop which have been worked up to date on an extensive scale, but as occasion arises that which occurs in other areas will probably be used.

Happy Valley.

A quarry has been opened on the Happy Valley road near Stafford, and quite recently several specimens of precious opal have been obtained there.

The mineral, which so far has not been found in any quantity, shows the beautiful play of colours seen in the more valuable opal. This is the only locality known to the author in which precious opal has been found in the tuff, although a few isolated specimens of common opal have been obtained from the Windsor quarry.

The tuff itself resembles that found in other parts of Brisbane, showing great variety in colour, hardness, etc., although the specimens containing the opal were all of a deep-purple tint.

At the base of the quarry the rock shows a distinct tendency towards bedding.

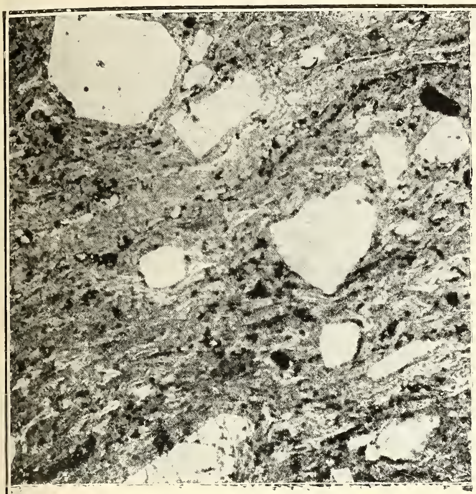
ACKNOWLEDGMENT.

In conclusion, the author wishes to thank Dr. Bryan, of University of Queensland, for his generous and invaluable assistance in revising this work, Professor Richards for assistance and encouragement, Mr. Patten for making the chemical analysis, Mr. A. N. Falk for preparing the microphotographs, and her fellow students who accompanied her on the more far-distant field excursions.

PLATE VIII.

Microphotographs of specimens of the Brisbane Tuff taken in ordinary transmitted light.

1. Typical tuff from Morningside ×14.
2. Typical tuff from Collin's Wharf ×14.
3. Typical tuff from Morningside ×30.
4. Typical tuff from Morningside ×30.
5. Hard band at base of tuff, Gotha street, ×30.
6. Hard band at base of tuff, Collin's Wharf, ×30.



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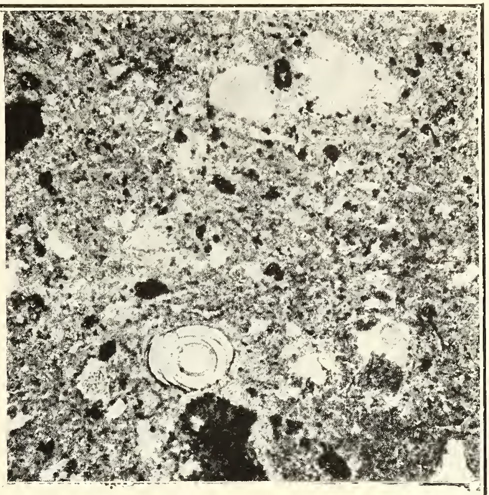

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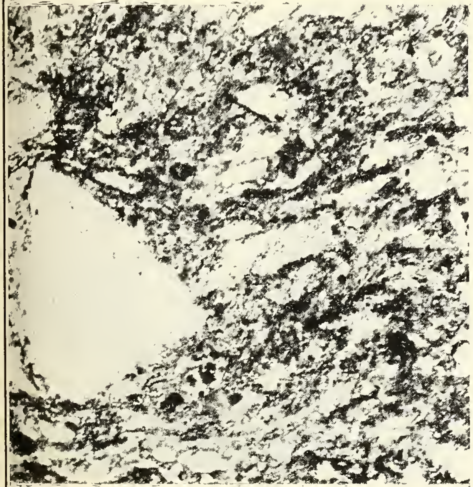

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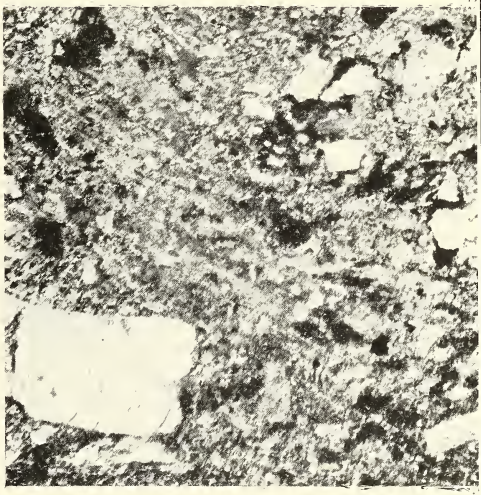

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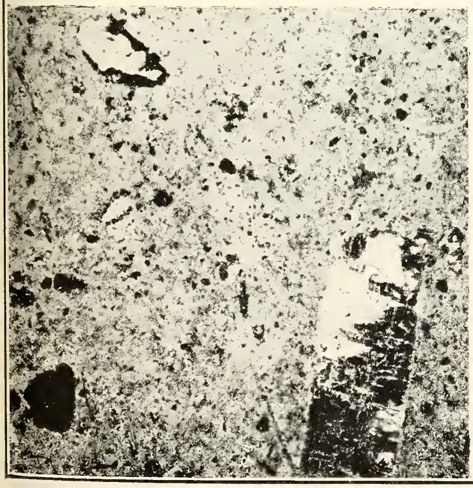

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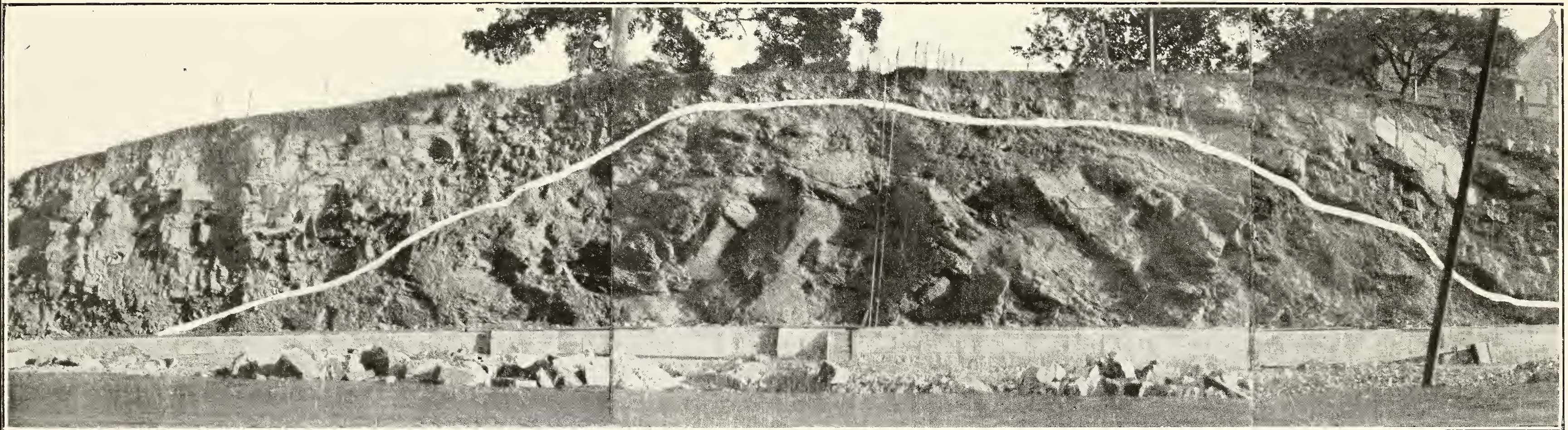
[Face page 164.]



Photograph of cutting in Ann street, Brisbane, to show the relationship of the Brisbane Tuff to the Brisbane Schists. The white line has been drawn to mark the position of the base of the Brisbane Tuff. Between this and the Brisbane Schists there are a few feet of freshwater shales. The section has now disappeared, having been removed in the preparation of the foundations of the Cathedral of the Holy Name. The partly constructed wall is built of blocks of Brisbane Tuff quarried almost *in situ*.

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The Major Factors in the Present Distribution of the Genus Eucalyptus.

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(*Read before the Royal Society of Queensland, 26th November, 1928.*)

The genus Eucalyptus to-day ranges from Tasmania in the south to Mindanao in the north. By far the greatest number is found in Australia and its continental islands, four Australian species extending beyond the continent to eastern Malaysia, two others being endemic there. The island of Flores represents the westernmost outpost of the genus in the Malaysian Islands, and the New Britain Archipelago the easternmost. Great gaps indicate a former wider distribution in Malaysia. To-day most of the species of the genus are concentrated in the extra-tropical part of the continent, especially in the south-eastern and south-western corners.

Thanks to the monumental work of the late J. H. Maiden, our knowledge of the range of the species, though still far from complete, especially in the localities remote from the centres of settlement, is sufficiently advanced for a detailed examination of their distribution and for a revision of the earlier theories as to the origin and development of the genus. Such is the object of this paper. The nomenclature adopted is that accepted by J. H. Maiden in his Critical Revision of the Genus Eucalyptus (1). Though his judgment is by no means universally accepted in many cases, his work represents a single view-point of the genus as a whole, and an unreserved acceptance of his naming for all species avoids the lack of balance which would be unavoidable were other opinions taken into account. Baker and Smith, for example, are less conservative in their definition of species than Maiden, and their census of plants of their State (New South Wales) would include a large number of names which are regarded as synonyms in the Critical Revision. In Western Australia, Maiden's conception of the genus is usually accepted, and most of the more recently described species from that State have been named by him. It would therefore give New South Wales an inflated census as compared with Western Australia were the justice of Baker and Smith's contentions to be considered. As this paper is largely comparative, the tendency of a single authority to conservatism or errors in the delimitation of species, if such a tendency is claimed, is largely cancelled.

SURVEY OF LITERATURE.

The question of the origin of the Australian flora was first considered systematically by J. D. Hooker (2) in his introductory essay to the Tasmanian Flora, published in 1860. He pointed out that the dominant families of Australia were for the most part dominant in other parts of the world. Of the nine largest families in Australia six are the largest in the world, while the peculiarly Australian families are few. He recognised in addition to the autochthonous element the presence of Indian, Malayan, and Polynesian types in the north, New Zealand and South American types in the south-east, and an African element in the south-west. An assemblage of New Zealand, Fuegian, Andean, and European genera on the mountain tops was regarded by him as possibly the result of immigration, though in some cases the possibility of the alteration of Australian types was not lost sight of.

A considerable literature has grown up round the subject of the origin of the genus Eucalyptus, and the almost unanimous opinion of recent writers is that it originated in the warmer parts of the continent. Deane (3), for example, regarded the north and north-east as the original home of the capsular fruited Myrtaceæ, and that from these developed the fleshy fruited types of the family which spread to Asia and the other continents. The distribution of the Myrtaceæ is against such a hypothesis, as has been pointed out by Andrews, and capsular fruits are not necessarily always ancestral to baccate types. One point, however, is that Deane looks on the north as the starting point of the genus. Cambage (4, 5) considers that the early Eucalypts flourished in a warm climate, probably in Northern Australia. Andrews (6) is of the same opinion, reached by a consideration of the Myrtaceæ as a whole.

The earlier work where special attention was given to the history of Eucalyptus was that of Unger (7) and Ettingshausen (8). In 1865 Unger's work on "New Holland in Europe" appeared in the Journal of Botany. This was a translation of a lecture given by him in 1861, in which he presented the fossil evidence of the presence in the Eocene of Australian types in Europe. Araucarias, Eucalypts, Santalaceæ, and Proteaceæ were described, and the conclusion reached that New Holland plants had travelled across a continental connection through Asia to Europe in the Eocene, and that at that time the European climate was similar to that of Australia at the present day. Unger's work did not long go unchallenged. Bentham in 1870, criticising the paper, pointed out that a modern systematist would not determine the order and genus of an unpublished species on the evidence of a leaf fragment. Ettingshausen (1883) viewed the tertiary Australian flora as a cosmopolitan one, comparing its fossil Eucalypts with those described from Europe, the Arctic Zone, and America. The dissociation of mixed floras such as those of the Eocene into elements now found in different climatic zones has more recently been stressed by Guppy in his Theory of Differentiation. Palms and poplars then found together are now separated. Ettingshausen's conception of the Australian Eocene flora was that of mixed types, the Eucalypts having since died out elsewhere. His deductions are based on fossil evidence, the soundness of much of which has been repeatedly questioned. Deane in 1896 attacked his conclusions as to a cosmopolitan tertiary flora, pointing out that there was nothing to prove that Australian groups existed outside Australia in tertiary times. Specimens referred to the genus Eucalyptus in North

America are now regarded by Berry (9) as being closer to *Myrcia* and *Eugenia.* This authority suggests that the Eucalyptus-like remains in North America be referred to the genus *Myrcia,* or alternatively to Heer's genus *Myrtophyllum,* which contains those Myrtaceæ represented by leaves whose generic relations cannot be determined with certainty. Amongst the European forms described as Eucalyptus are *E. oceanica* Unger and *E. Geinitzi* Heer; the former is similar to *Myrcia vera* Berry from the North American Eocene, and the latter is amongst those types referred to *Myrcia* or *Myrtophyllum.*

From the point of view of origin of the genus Eucalyptus the fossil evidence seems to point to a local development rather than to a former cosmopolitan distribution. The fossil Eucalypts described from Europe and America are from leaf material only, except in a few cases, and Maiden never saw a fruit referred to the Cretaceous or Tertiary that he agreed in referring to the genus.

Undoubted Eucalyptus remains from Australia have been described from Tasmania, Victoria, New South Wales, Queensland, and South Australia by McCoy, R. M. Johnson, Ettingshausen, Deane, Chapman, Patton, and others. Sub-fossil remains assigned to *E. obliqua,* to the *amygdalina* type, *E.* cf. *melliodora,* and *E.* aff. *piperita,* have been reported and are listed by Chapman (10).

Eucalypts with transverse leaf venation extended to Tasmania in the Eocene, *E. Kayseri* and *E. milligani* being of this type. Deane (11) points out that this is about 4° farther south than the present southern limit of the transverse type, and is to be expected considering the difference of climate in the Eocene and Miocene. Chapman records leaves of the *amygdalina* type, probably Miocene, from Redruth (Victoria). Ettingshausen's fossil plants from Oxley and Darra were assigned by him to the Cretaceous, but are now regarded as Tertiary; Jones (12) tentatively places the Redbank Plains series, in which they were found, as Eocene or Oligocene. Amongst the plants described are Eucalypts of the transverse and oblique types of venation. Fragmentary though it may be, the fossil evidence indicates that the earliest leaf types discovered were differentiated into transverse and oblique types, and that the extreme obliquity of vein angle of the *amygdalina* type was also developed back in the Tertiary.

Baker and Smith (13) in 1902 formulated a diagram showing their conception of the evolution of the Eucalypts as evidenced by their botanical and chemical characters. Their work was founded mainly on the chemical constituents of the oils of the species examined. "Assuming Angophora to be the older genus," they pictured Eucalyptus as developing through *E. tessellaris* and *E. trachyphloia,* and a genealogical tree with numerous side branches was constructed from the living species. Species of undoubted affinity, such as *E. maculata* and *E. citriodora,* were widely separated in their scheme. In the second edition of their work (1920) they present a diagram of the same type, but with more species included and with definite places for some species previously placed only provisionally. Some alterations have been made in the placing of a few species. Here for example, *E. citriodora* is shown as a descendant of *E. maculata*. *E. rostrata* is shown as a descendant of *E. tereticornis*, and many of the lines consist of chains of related species. *E. rostrata* var. *borealis* is, however, given quite a different line of descent from *E. rostrata*. This variety was established by Baker and Smith on chemical characters only; morphologically it is indistinguishable from the typical *rostrata*. To give such a variety a different line of descent is in itself a condemnation either of the genealogical table which would separate a variety from its parent in such a way, or of the value of chemical constitution as a taxonomic character. The Western Australian endemic species, *E. gomphocephala*, which is restricted to the coastal limestone, is shown with a series of immediate ancestors which are restricted to the south-eastern portion of the continent. The series is *Risdoni, Gunnii, Luehmannii, tœniola, gomphocephala*. *E. Risdoni* and *E. tœniola* are Tasmanian endemics; *E. Gunnii* is Tasmanian and S. E. Australian; and *E. Luehmannii* is a New South Wales species. *E. elæophora* of S. E. Australia is shown descended from the pan-Australian *E. rostrata* through the Western Australian endemics *marginata, occidentalis,* and *salubris*. The geographical range of these and other examples that might be taken is, to say the least of it, not in harmony with such a genealogy, and, when considered in conjunction with the lack of morphological affinity between many of the species, shows the misleading and inaccurate nature of such a table.

Andrews suggests that the presence of phellandrene and certain other constituents in the oils of some species is of importance, at least in part, in resistance to cold, because the Metrosidereæ and Myrtaceæ are not as resistant as the Eucalypts containing these oils. This he regards as an important acquisition from the point of view of the development of the genus. Cuthbert Hall (14), in his work on the evolution of the Eucalypts in relation to the cotyledons and seedlings, carried the idea further. "*E. macrorhyncha* and *E. capitellata* . . . by the development of a pinene-eucalyptol-phellandrene oil have been enabled to spread over the south-eastern States and to work on to the mountains; while *E. obliqua*, by the development of a piperitone oil, has been able to establish itself over the mountains from the Queensland border to southern Tasmania." Again, "Chemically they (the *corymbosa* group) do not seem to have made much progress and have failed to develop eucalyptol, phellandrene, piperitone, aromadendrol, and so have been unable to leave a sandstone formation or to penetrate to the high alpine regions or dry interior."

Such assumptions as these are too great a load for the evidence to bear. The function of the essential oils in the metabolism of the plant is very uncertain. Doubtless they often have a protective effect against potential enemies, but their physiological function, if any, is unknown.

The history of the genus according to Cambage, as expressed in his various important papers on the subject, is briefly as follows:—

> Originating in the warmer parts of Australia the early Eucalypts were of the bloodwood type. Their leaves were opposite and horizontal, and had transverse venation; the anthers opened in parallel slits, and the fruits were generally larger than those of the present day; the main constituent of the oil was pinene. From this early type new types evolved by the development of petioles, oblique venation of the leaves, and various bark textures. Amongst these the Boxes, whose anthers open in terminal pores, have cineol as an important oil constituent. In cooler regions the Renantheræ, with kidney-shaped anthers, developed; here pinene is a very minor oil constituent, if present at all; the leaves have an almost parallel venation or with the few lateral veins showing an angle of less than 25° with the midrib. The Peppermints are included in this group, in which the greater vein-angle of the juvenile foliage indicates that the ancestral forms had a more transverse venation. The Miocene climate was mild and warm and Eastern Australia fairly level. The uplift which resulted in the formation of the Main Divide at the close of the Tertiary (the Kosciusko period) had a pronounced effect on the distribution of Eucalypts. Three distinct climatic zones were created—the moister eastern face of the mountains, the drier western slopes, and the cooler mountain regions. None of the Eucalypts of the interior occur in Tasmania. The renantherous types have migrated northwards along the mountains into southern Queensland, perhaps assisted by the Pleistocene glaciation period.

Dr. Cuthbert Hall's work on the cotyledons and seedlings shows that their morphology is a valuable taxonomic character. The cotyledons of the various species of Angophora, except *A. cordifolia*, are reniform like those of the Bloodwoods, and indistinguishable from them. The primary leaves of the latter, however, become petiolate and later alternate and often peltate. He classes the cotyledons into two groups, entire and emarginate; the reniform bloodwood type and the Y-shaped type, illustrated by *E. cornuta* and other species (both eastern and western), being at either end of the series. The shape of the cotyledon is useful in determining the affinities of many species, and the evolution of cotyledonary types has progressed along definite lines. Hall attempts to correlate this with adaptation to "Australian conditions" (p. 525). He pictures the necessity for the reduction of the large bloodwood cotyledon shown in *E. trachyphloia*, the evolution of the deeply bifid cotyledon in Western Australia and as far north as Western Queensland. Reduction of cotyledons, however, is not confined to dry areas, and these organs are ephemeral, representing a stage of the plant's life history usually passed under favourable moisture conditions. The various types contain widely differing species of Eucalypts, and in a number of cases natural groups (based on other characters) have members with different types of cotyledons. It seems that various types have been produced independently in various parts of Australia, and that this character, like most of the others which are valuable in Eucalyptus taxonomy, has its limits and cannot be applied as a test of the past behaviour of the genus, evolutionary or geographical, except with extreme caution.

FACTORS GOVERNING THE DISTRIBUTION OF THE GENUS.

Dr. J. C. Willis (15), in a series of papers and in his book, has propounded the Age and Area Theory, which may be expressed in the following terms:—

> The area occupied (determined by the most outlying stations) at any given time in any given country by any group of allied species at least ten in number, depends chiefly, so long as conditions remain reasonably constant, upon the ages of the species of that group in that country, but may be enormously modified by such factors as the following:—Chance (the operation of factors not yet understood); the action of man in opening up a country, cutting of forest, exploring, making fires, etc.; interposition of barriers such as mountains, arms of the sea, broad rivers, deserts, sudden changes of climate from one district to another, and the like; geological changes, especially if involving changes of climate; serious changes of climate; natural selection; local adaptation; dying out of occasional old species; arrival of a species at its climatic limit; density of vegetation upon the ground at the time of arrival of a species; presence or absence of mountain chains in the land over which the species has to travel in arriving; relative width of union between country of departure and that of arrival (the wider it is the more rapid may be the spread of the species in the new country).

This definition is compiled from two of Willis's papers. In floral invasions he predicts that if a species enter a country and give rise casually to new (endemic) species, then if the country be divided into equal zones it will generally occur that the endemic species occupy the zones in numbers increasing from the outer margins to some point near the centre at which the parent entered. He has applied his hypothesis to New Zealand, and found that there were three maxima, corresponding, in his opinion, to three points of invasion—a northern, a central, and a southern. Willis's theory has many critics, and much of their criticism is answered by him in his various papers in the "Annals of Botany."

One of the points of importance that emerges from the mass of literature that has sprung up on the subject of age and area is the importance of relic species of endemics. We are chiefly indebted to Sinnott (16) for the attention that has been given to this matter. His objections were shown to be well founded in the case of the North American flora, which was the one with which he was most familiar. There, owing to the past changes of climate, the numbers of relic species are relatively great, and their importance cannot be overlooked. Guppy (17), one of Willis's chief supporters in the theory, investigated the flora of the Canary Islands, a region with a number of undoubted Tertiary relics. and found that this type of endemic had on an average a wider distribution than the more recent Mediterranean type. Thus from this quarter the age and area hypothesis received further support.

The genus Eucalyptus contains over 250 species, a sufficient number for an attempted application of the age and area hypothesis as a test for their point of origin. It is first necessary to study the various factors modifying its operation. Man's effect has been negligible. A species like *E. mundijongensis* might be wiped out easily, but there is no evidence of the recent extinction of species of Eucalyptus by man, though the periodic firing of the forests by the natives restricted local distribution in Gippsland.

THE EUCALYPTUS PROVINCES DEFINED.

For a comparison of the Eucalypt population of the various parts of Australia it is necessary to divide the continent into provinces. Tasmania by reason of its isolation is a natural province, but the delimitation of boundaries on the mainland is difficult. The political boundaries are of no use, because they are artificial and the States are of widely different sizes. As a guide a large map of Australia was prepared and the range of each species represented in outline. Some are of such restricted range that they had to be represented by dots. The completed map was covered with a tangle of irregular oval and triangular areas and liberally sprinkled with dots. One thing, however, was plain. There were a number of areas scattered round the margin of the continent in which the concentration of species was very marked. The most prominent of these were eastern Victoria and southern New South Wales, the area between Sydney and Newcastle, the area between the Northern Rivers of New South Wales and Brisbane, the Rockhampton area (to a less marked extent), the Cairns district, the Northern Territory, the Kimberleys, the extreme south-west of Western Australia, the country east of Albany and north-west from there through the wheat belt, the Western Australian goldfields, and finally south-eastern South Australia and western Victoria. Tasmania had previously been cut off because of its natural isolation. Measurement showed that these centres of present distribution could be circumscribed for the most part by areas about 500 miles long and 200 miles wide. The heart of Australia, poor in species, could not be divided up into small centres, but western New South Wales and Queensland had a number of dry-country species and could be marked off fairly definitely into a strip about 200 miles wide. Going round Australia the coast was marked off into the regions indicated by the concentration centres in sections each approximately 500 miles long. In Western Australia the Kimberleys marked one natural region. West of Roebuck Bay is a long stretch of country poor in Eucalypts right round to Sharks Bay. This was divided into two regions, however, for the sake of uniformity and also because below the north-west cape the rain falls mainly in winter. In south-western Australia one area was marked off from the Irwin River to a point a little east of Albany, another from Sharks Bay to Esperance, and the remainder, the goldfields division, took in the concentration centre round Coolgardie. Though this latter area is somewhat larger than usual its endemic Eucalypts are mainly concentrated around Coolgardie, and a much smaller area would give almost the same census. From Eucla to Port Lincoln the arid Bight country was marked off, and because many of the species here pushed into arid western New South Wales the area was continued east, cutting off the south-eastern part of South Australia, which, with western Victoria, constituted another province. A strip of western New South Wales contained a small but characteristic collection of Eucalypts. The great arid area left after the separation of these strips was not divided up, for it contained only seventeen species altogether.

Though Australia is conveniently divided into a number of fairly definite regions in this way there is a good deal of overlapping. A tongue of southern vegetation, for example, extends into Southern Queensland along the New England Range; in Western Australia, goldfields forms are found occupying the wheat belt in local patches; and at Rockhampton western Eucalypts cross the divide and reach the coast.

Those species occupying more than one of these regions are regarded as wides, those occupying one only as endemics, the word "endemic" here being used to indicate endemism with regard to the province only.

ISOLATION.

The effect of isolation on endemism is well shown in the case of Tasmania. Of its twenty-four species and varieties, thirteen are restricted to the island. The others occur also on the mainland, and of these five are in Victoria and adjacent parts of New South Wales only. The endemic species are all related to mainland species, eleven of them belonging to the *amygdalina* group. Newly developed species arising in Tasmania have been unable to spread to the mainland, being cut off by Bass Strait. The enforced restriction of locality means that a number of species which, given a chance to extend their territory, might have become wides, must remain endemic. Comparing its Eucalypt population with that of eastern Victoria and southern New South Wales we find that, though conditions are similar ecologically, the relative numbers of species of restricted range are much smaller. Taking the eighty-two species and varieties of the genus from the south-eastern corner, it is found that fifty-eight are wides (all of them extending farther north, and a few pushing west to South Australia), the remainder being endemic. Reduced to a common basis, Tasmania has 50 per cent. endemic species, the adjacent south-eastern corner of Australia as far north as, say, Kiama, 31·7.

South-western Australia is not as effectively isolated by the arid country as Tasmania is by the sea. It has six species in common with eastern Australia, and one with the northern part of the continent. These are dry-country forms which stretch across the intervening space. Against these there are 116 members of the genus which do not extend beyond the extra-tropical part of the State. As far as Eucalypts are concerned, therefore, temperate Western Australia is very isolated. In the extreme south-west where the rainfall in places exceeds 40 inches per annum, the country is heavily timbered. Inland the annual rainfall falls off rapidly, and three very distinct zones may be marked off—the well-watered south-western corner, approximately delimited by a line drawn from the Irwin River to a little east of Albany; a drier belt (including the wheat belt) from approximately Sharks Bay to Esperance; and the still drier goldfields area. On the east the goldfields area merges into the arid country of Central Australia and the Nullarbor Plain where the species of Eucalypts are few.

Corresponding to the differences in the rainfalls of these regions we have marked difference in the Eucalypt flora. The belts are rather isolated from one another by reason of their rainfalls, and the species endemic to them are characteristic. In the extreme south-west a few examples are *E. marginata, diversicolor, Jacksoni, Guilfoylei, ficifolia,* and *Todtiana*. In the drier belt *E. Forrestiana, Dongarrensis, Kondininensis,* and *cæsia* are amongst the endemics, though some of the most characteristic species, such as the York Gum (*E. fœcunda* var. *loxophleba*) are wides, overlapping a little into other belts. In the goldfields belt species of restricted range include *E. crucis, torquata, Jutsoni, corrugata, Le Souefii,* and *diptera*. The endemism in each of these areas is remarkably high, and is even more marked than that of Tasmania. In the south-western corner (Irwin River to Albany) there are twenty-five species endemic in a total of forty-two; this is equivalent to 59·7 per cent. In the drier belt inland from this and reaching to a line drawn from Sharks Bay to Esperance there are seventy members of the genus, and thirty-nine of them (or 55·5 per cent.) are restricted. In the goldfields area thirty-four out of fifty-three (or 66 per cent.) are not found beyond the region. The high percentages in this part of Australia point to long isolation. The actual number of species in the western part of extra-tropical Australia is smaller than that of the eastern half. Many of the newer species of Western Australia have been unable to extend their territory because of climatic barriers, whereas in the east, where the possibilities of spreading are much greater owing to the more or less uniform rainfall along the coast, the number of wides is proportionally greater. In the east, too, the mountains run north and south, and species are enabled to push farther north on the highlands than they could on the lowlands. In the three mentioned areas of Western Australia there are ninety-eight endemics and thirty-four wides—that is, 74·2 per cent. endemism. Three extra-tropical areas in eastern Australia (from Victoria northwards to Maryborough) have seventy-seven endemics and eighty-one wides; this is equivalent to 48·7 per cent. endemism for the whole area.

These figures may be summarised as follows:—

Table I.—Comparative Endemism in Tasmania, South-western Australia (Irwin River to Albany), and in Victoria and Southern New South Wales.

——	Endemics.	Wides.	Total.	Per Cent. Endemism.
Tasmania	13	13	26	50·0
South-western Australia	25	17	42	59·7
Victoria and Southern New South Wales	27	58	85	31·7

Table 2.—Comparative Endemism in Extra-tropical Eastern Australia and Extra-tropical Western Australia.

——	Endemics.	Wides.	Total.	Per Cent. Endemism.
Extra-tropical Eastern Australia : Victoria to Maryborough (three areas)	77	81	158	48·7
Extra-tropical Western Australia : Sharks Bay to Eucla (three areas)	98	34	132	74·2

These figures speak for themselves as regards the effect of isolation on endemism. The major isolated zones are those of Tasmania and temperate Western Australia, and the contrast is shown against zones where expansion is possible. There are in addition numerous small isolated regions such as the coastal dune limestone of Western Australia, or the highlands in North Queensland. In the former we have a characteristic endemic species in the tuart (*E. gomphocephala*) which does not occupy the neighbouring granite country. In the region between Bowen and Princess Charlotte Bay there is an increase in the percentage of restricted species as compared with areas of similar size elsewhere in Northern Australia. Here we have nine endemics in a total of thirty (30 per cent.). The contrast with adjacent regions is not so marked as that between the Western Australian regions and some of those of the east, but it is striking. It may be shown in tabular form:—

Area.	Endemics.	Wides.	Total.	Per Cent. Endemism.
Maryborough to Bowen	3	26	29	10·3
Bowen to Princess Charlotte Bay ..	9	21	30	30·0
Gulf Country to North Australian Border	3	19	22	13·6
North Australia (N.T.)	5	21	26	19·2
Kimberleys	7	22	29	24·1

It will be noticed that the percentage has risen again when we come to the Kimberleys in northern Western Australia. Here again we have mountainous country, though not of so pronounced a character as that behind Cairns. The number of species is so low that one or two extra make a great deal of difference. If two of the mountain species, such as *confluens* and *argillacea,* were undiscovered, the percentage endemism would be comparative with that of the Northern Territory.

Such outlying regions with different climatic conditions from the surrounding country would naturally be expected to develop a somewhat different, though related, flora, and the sharp contrast in climate would tend to check the expansion of new species, thus producing a higher proportion of endemics.

On mountain tops are a few species of very limited range. *E. alpina* is in the highest parts of the Grampians; *E. parviflora* at Nimitybelle (3,500 feet); *E. de Beuzevillei* on summits in the Kosciusko district; *E. Mitchelli* on Mount Buffalo; *E. Moorei* on the highest parts of the Blue Mountains from Wentworth to Mount Wilson; and *E. Mooreana* on summits in the Kimberleys. *E. virgata* has given rise to *E. virgata* var. *fraxinoides* in the Monaro, and to *E. virgata* var. *triflora* in the Pigeon House Mountain (N.S.W.).

TEMPERATURE.

From the point of view of vegetation the tropical portion of eastern Australia may be said to be that portion of the country from about Maryborough north. South of this the winter frosts gradually eliminate the northern forms, though some extend as far south as Victoria. Such a boundary applies also to the Eucalypts. Coastal eastern Australia lends itself readily to migration within temperature limits, there being a long strip of land along the coast from Victoria to North Queensland with no pronounced physiographical barriers. The mountains run north and south. From the Northern Rivers of New South Wales northward the rainfall mostly occurs in the summer; south of that it is mostly in winter, but the transition is gradual.

A comparison of the various parts of the coastal belt, leaving out Tasmania on account of the effect of isolation on its flora, may be made by considering the total number of species and the number of endemics in the following coastal regions:—(*a*) Eastern Victoria and southern New South Wales; (*b*) New South Wales as far north as Raleigh; (*c*) Northern Rivers of New South Wales and South Queensland as far north as Maryborough; (*d*) Central Queensland (Maryborough to Mackay); (*e*) North Queensland (Mackay to Princess Charlotte Bay).

TABLE 3.—COMPARATIVE ENDEMISM IN TEMPERATE AND TROPICAL EASTERN AUSTRALIA.

Area.	Endemics.	Total.	Per Cent. Endemism.
Eastern Victoria and Southern New South Wales..	27	85	31·7
Coastal Central New South Wales	36	111	32·4
Northern Rivers and South Queensland	14	71	19·7
Central Queensland	3	29	10·3
North Queensland	9	30	30·0

The greater number of Eucalypts in this coastal belt is located in the temperate zone. The high percentage of endemism of North Queensland is associated with the presence of the highlands and accompanying isolation. Three other regions of tropical Australia—the Gulf of Carpentaria country, Northern Territory, and the Kimberleys—may also be considered. The figures for these parts are as follow:—

TABLE 4.—ENDEMISM IN NORTHERN AUSTRALIA.

Region.	Endemics.	Total.	Per Cent. Endemism.
Gulf Country	3	22	13·6
North Australia	5	26	19·2
Kimberleys	7	29	24·1

It will be seen that for areas of about equal size the total number of species of Eucalypts is approximately equal, and that the number of endemics varies a little, especially in regions of rugged physiography. The numbers rise sharply as we go south, unless, of course, we push into the dry country (where, as is pointed out later, the genus is relatively unsuccessful in eastern Australia), and the endemism is also, on the whole, higher.

Taking the whole of tropical Australia and comparing it with the whole of the extra-tropical portion of the continent, we find that there are 30 species of narrow range and 39 of wide range in the tropics, while in the temperate portion there are 202 of narrow range and 93 wides. These figures include the two dry regions, western New South Wales to western Queensland and Central Australia, each of which lies on both sides of the equator. Fifteen of the western New South Wales and Queensland species are southern, two northern, and two common. In Central Australia eight are southern, six northern, and three common. Here in the dry country the greater development is in the cooler south, which is in keeping with the distribution in the better watered regions. The overlapping of species in temperate and tropical Australia is not great. *E. peltata, acmenioides, eugenioides, saligna, eudesmioides, tereticornis, pyrophora, Cloeziana, exserta, rostrata, tessellaris, corymbosa, terminalis, bicolor, hemiphloia, microtheca, crebra, and melanophloia* are found in both. *E. Baileyana,* though mainly temperate, also overlaps a little. This overlapping takes place mostly in the east, one dry-country form, *E. eudesmioides,* being the only western Eucalypt found in both tropic and temperate zones. I am indebted to Mr. C. T. White for some notes on the tropical range of some of these species.

The overlapping of species in the eastern part of Australia, where the temperate zone grades off into the tropical, may be used as a test for the direction of migration of the Eucalypts. In the area which takes in north-western New South Wales and south-eastern Queensland we have fifty-eight species of wide distribution. Of these, twenty are found in the tropics and fifty-one in the more temperate parts of New South Wales and Victoria. Only six are found extending north and not south. Even if we exclude ten species such as *E. obliqua, E. regnans, E. altior,* etc., which occur on the New England Tableland and which are rather a special tongue from the south, we still have forty-one wides left which extend south—that is, twice as many as extend north.

The wides in Central Queensland and Northern Queensland are fewer than in the southern part of the State. North of Maryborough to Bowen the total falls to twenty-six. Seventeen have tropical distribution only: sixteen extend into the temperate zone. North Queensland, with its twenty-one wides, has eleven in the temperate zone; seventeen of the total are in Central Queensland. Here in these two tropical provinces the great preponderance of southern forms which was so marked in the region embracing northern New South Wales and southern Queensland is missing. If, however, a map of Queensland is drawn with the distribution of its Eucalypts marked in, it is seen that the areas do not centre in the north, but that the wides extend to different distances, many stopping just north of Rockhampton, others pushing up a little further and a little further like a series of waves lapping on a beach. There is no definite northern centre for the eastern wides, nor is there any approach to one. Such a map indicates, if anything, an encroachment from the south. Wides of purely tropical distribution are for the most part spread across Northern Australia fairly evenly, circumscribed by climatic barriers, and in mountainous regions showing an increase in the number of their associated (and derived) endemics.

RAINFALL.

A line drawn across Southern Australia from east to west from Perth to Newcastle passes through country of very diverse rainfall. Perth lies in an area having a rainfall of between 30 and 40 inches per annum. Then comes the wheat belt (20 to 30 inches), the goldfields (10 to 20), the dry interior (under 10), western New South Wales (10 to 20), and the eastern slopes and coastal plains of New South Wales (20 to 40, and in places even more). The numbers of Eucalypts and the proportions of endemics in these areas are as follow:—

Table 5.—Comparison of Eucalyptus Population and Endemism in Provinces from Perth to Newcastle.

——	Rainfall.	Endemics.	Total Species.	Per Cent.
	Inches.			
South-west Australia	30–40	25	42	59·7
Wheat Belt	20–30	39	70	55·5
Goldfields	10–20	34	53	66·0
Arid South Australia	Under 10	2	19	10·5
Western New South Wales	10–20	6	22	27·2
Coastal New South Wales	20–40 (or more)	36	75	32·4

The total number of species and the proportion of endemics fall off rapidly in New South Wales as we go west from the regions of higher rainfall, reaching a minimum in the arid interior of the continent. On the western side it rises sharply again, but there is not the same sharp gradation in numbers from dry to well-watered areas. The country within about 100 miles radius of Coolgardie is a spawning ground for dry-country species, and the greater proportion of the species endemic to this 10 to 20 inch rainfall are centred there. Nineteen of its species are wides and thirty-four are endemics. Five of the former are allies of *E. incrassata,* and so are nine of the endemics; that is to say, over one-quarter of the Eucalypts of the region belong to one advanced group. Ten of the remainder are allies of *Eucalyptus oleosa* (six wides and four endemics). The range of affinities in the species left over is not great. Nearly half of the forms found in the region are due to the multiplication of two groups. (In a more exaggerated way we see the Eucalypt flora of Tasmania composed largely of allies of *E. amygdalina.*) Were it not for these two successful groups we should have figures more comparable with those quoted for western New South Wales and western Queensland.

In the wheat belt of Western Australia ten of the seventy species are *incrassata* allies; six are wides and four restricted. They represent an invasion from the goldfields, and their exclusion makes practically no difference to the proportion of endemics in the area. The *incrassata* group centres in the goldfields, and, though it extends eastward and westward, it has not had the same success as round the Coolgardie region; in the wheat belt its members are an overflow from the dry country.

In the drier belts of Western Australia it is an outstanding fact that the Eucalypts are much more successful than they are in similar areas in the east, and no doubt the long-continued stability of that portion of the continent has favoured a slow and steady development of eremean types.

Eucalyptus is not such a successful type in the areas with a rainfall of less than 10 inches per annum. In the arid belt extending from the Western Australian border to western New South Wales there are nineteen species altogether, two only being endemic; they are mostly of the *incrassata* and *oleosa* type. In the country of similar rainfall from Sharks Bay north to the North-west Cape there are only three species recorded—*rostrata*, *dichromophloia*, and *microtheca*. Beyond this from North-west Cape to Roebuck Bay there are four wides and no endemics, though the rainfall is better and in places about 20 inches per annum is received.

The great tract of arid country in the middle of the continent possesses only seventeen species of Eucalypts, five of which have a more or less restricted range. This great stretch of land is equal in extent to the whole of coastal eastern Australia, where about 200 species are found.

EREMEAN TYPES.

The arid stretch of country from the Great Australian Bight to North Australia is thus indicated as a very effective barrier against Eucalyptus migration. Stretching as it does from sea to sea, there is little chance of species avoiding it by skirting the coast from east to west as they do from north to south in Eastern Australia. There are a number of species which extend right across—for example, *E. rostrata, dumosa, gracilis, transcontinentalis, oleosa, calycogona, incrassata, bicolor, leptophylla, pyriformis*, etc.; but with the exception of *E. rostrata* these are dry-country forms which do not connect the well-watered areas of east and west. There are two possible explanations of the eremean Eucalypts. They may represent an invasion of the arid region from either west or east, or they may be the present-day representatives of the survivors from a flora adapted to moister conditions. The great development of eremean types in the Western Australian goldfields country, which has already been alluded to, would suggest the former hypothesis, and the long-continued stability of the western part of the continent would be favourable to its behaving as a reservoir of potential plant colonists. On either side of the arid country, however, we find a few species—*E. diversifolia, E. conglobata, E. angulosa, E. Floctoniæ*, and perhaps *E. Gillii*—with eastern and western distribution, but not found in the intermediate area. *E. Gillii*, however, is only doubtfully recorded from Coolgardie. *E. gracilis*, though extending across the continent from east to west, has a big break in its known distribution before it reappears at Normanton.

Eucalyptus rostrata, the Red Gum, which is spread over the greater part of the continent, is a special case. It is found in both east and west, in the dry country restricted to watercourses in moister regions ascending the hill-sides. It does not occur in Tasmania, but as it is also absent from south-west Australia and parts of South Australia, this is not necessarily due to its youth. It has allies on both sides of Australia—*E. tereticornis*, for example, in the east, and *E. rudis* in the west. *E. rudis* shows marked resemblance to the eastern *E. ovata*, and there are other vague indications of an earlier widespread and larger group of these allies. There is not sufficient evidence, however, to show whether *E. rostrata* has used the watercourses of the interior as migration lines, or whether these are its last refuges.

The distribution of the other species mentioned seems to indicate that the eremean Eucalypts are the descendants of survivors rather than of immigrants from neighbouring botanical provinces, and that, therefore, *E. oleosa* and *E. incrassata* groups have lost ground. Much more definite evidence, however, is obtained by a study of the Corymbosæ and the Eudesmieæ.

Corymbosæ.

Thirty species and one variety of the important Corymbosæ or Bloodwood group are found in Australia, mostly in coastal localities. None are found in Tasmania or in New Guinea and the Malayan Islands. The present-day species are mostly tropical. Counting one variety (*E. pyrophora* var. *polycarpa*) as a species, for it is distinct from its parent species and has a definite range and cannot be omitted from a comparison, we have twenty-two tropical species and thirteen temperate. Four of these—*E. corymbosa*, *E. terminalis*, *E. maculata*, and *E. trachyphloia*—are common to both zones. In other words, eighteen are restricted to the tropics, nine to the temperate zone, and four overlap.

No bloodwoods occur in Tasmania. The type with transverse leaves was formerly present, as is shown by the fossil record. At present the bloodwoods show a distinct preference for the warmer portions of the continent. *E. corymbosa*, which is found from north-eastern Victoria to North Queensland, does not extend above 3,000 feet elevation in the mountains round Wentworth Falls (18), though the geological formation remains the same. Here we have an indication of the climatic limit of the species, and if we assume that an elevation of 900 feet is roughly equivalent to one degree latitude, it is seen that the southern limit of *E. corymbosa* is the climatic limit. It stops where it would be expected to. *E. eximia*, an endemic bloodwood of New South Wales extending from Jervis Bay to Hornsby, is recorded by Mr. Cambage as continuing to about 1,800 feet. It would appear, therefore, that at Jervis Bay it has reached its southern temperature limit.

In south-western Australia there are three members of the Corymbosæ. The mild temperature of the region does not set any barriers of this nature, and *E. calophylla*, the Marri or Red Gum, is widespread in the better watered parts to the south coast. The other species, *E. ficifolia* and *E. hæmatoxylon*, which occur almost in the extreme south-western corner of the State (*E. ficifolia* is found to the west of Albany, and *E. hæmatoxylon* between Jarrahwood and Busselton), are apparently young species. That *E. ficifolia* at least has not reached its climatic limits is shown by the way in which it flourishes in other parts of the south-west of the State, when planted. The real climatic barrier to *E. calophylla* is dryness. Its frontier is the edge of the wheat belt. No other bloodwoods are found in temperate Western Australia; the wheat belt and the drier areas beyond cut off the south-western bloodwoods from the rest of the group. They are the evidence of the retreat of this group from south-western Australia. To the north of the State their nearest relative is the widely spread *E. dichromophloia*, which stretches from the Murchison in Western Australia round the north of the continent to Central Queensland, but which does not make contact with the territory of the marri. It is one of those bloodwoods which can tolerate a very dry climate, and, indeed, in north-western Australia is one of the very few Eucalypts which can hold their own. Its southern limit is about the same in east and west of the continent. The rainfall at the western limit is mainly in the winter, and at the eastern mainly in the summer, and, as there is a wide range in its amount, this is not the limiting factor. Topography, soil, and rainfall alone would allow of a further extension south, but where the temperate flora becomes dominant this Eucalypt disappears. It is evident that here too, as in the case of *E. corymbosa*, we are dealing with a temperature limit to the range of the species.

In addition to *E. dichromophloia*, *E. ferruginea*, *E. peltata*, *E. Cliftoniana*, *E. pyrophora*, and its variety *polycarpa*, which are also tropical, are forms which are the outposts of the group in arid and semi-arid localities. The other species are limited for the most part to the well-watered fringe of Australia.

E. trachyphloia, found on Melville and Bathurst Islands, occurs again in Queensland around Rockhampton and on Percy Island (a little over 100 miles due north of Rockhampton) and in various localities south of Brisbane. The wide gap in North Queensland and the Northern Territory indicates a retrogression in the drier parts of tropical Australia. It is one of the yellow-barks, and its allies, *E. eximia*, *E. peltata*, and *E. Watsoniana*, are eastern. There is no existing species from which the Melville Island and Bathurst Island tree may have sprung independently. If such a species did exist at one time, and the distribution may be explained as an example of polyphylesis, the parent has died out, so that retrogression has taken place in any case.

The following is the present-day distribution of the Corymbosæ:—

TABLE 6.—PRESENT DISTRIBUTION OF THE CORYMBOSE EUCALYPTS.

Region.	Endemics.	Total.
Victoria and Southern New South Wales	1	4
Coastal New South Wales—Kiama to Northern Rivers ..	1	4
Northern Rivers to Maryborough	2	7
Central Queensland	0	7
North Queensland	2	8
Gulf Country	0	5
Northern Territory	2	11
Kimberleys	3	12
Broome to North-west Cape	0	1
North-west Cape to Murchison	0	1
Arid Interior	2	3
South-west Australia	3	3
Total Tropical	8	23
Total Temperate	8	13

The budding off of endemic species as indicated in the table follows no rule. The relative numbers of species of restricted range do not vary a great deal from area to area, the numbers being too small to show much contrast; the number of wides, however, varies markedly. The Kimberleys and the Northern Territory possess the greatest total of bloodwoods, and being surrounded by drier territory many are unable to extend their area. To the west the number of wides falls to one, to the south to one, and to the east to four. The Gulf country and the dry interior separate the eastern strip of Eucalypts from those of the north, and migration round the coast under present conditions in either direction is quite unlikely. The only widespread species with this range are *E. terminalis, E. dichromophloia,* and *E. trachyphloia.* The last-named has already been discussed. The other two can grow in sub-arid conditions, *E. terminalis* growing in relatively dry parts of western New South Wales and Queensland, *E. dichromophloia* being one of the few successful species in north-west Australia. The Gulf country has five species—*E. terminalis, E. dichromophloia, E. miniata, E. peltata,* and *E. setosa.* The first two are widely spread in the tropics, but the others have a distribution through the Northern Territory and the Kimberleys, and are not found in the eastern strip at all. *E. miniata* has a close relative, *E. phœnicea,* endemic in the Northern Territory. *E. ptychocarpa,* through which they are linked to the rest of the Corymbosæ, is a Kimberley and Northern Territory species. This does not prove anything, but is a slight indication that the central point from which it has spread was not eastern. *E. setosa* is in contact with its allies, *E. Cliftoniana* (endemic in the Kimberleys) and *E. ferruginea* in the western part of its territory. In the east it is not in touch with the closely allied *E. Torelliana,* an endemic of the east coast of North Queensland, which grows in competition with the Malayan element either in rain forest or on its fringes. *E. peltata,* the remaining Gulf species, is a dry-country form ranging south through the dry country to Chinchilla. It, too, is out of contact with *E. Torelliana,* its closest surviving relative.

E. Torelliana is thus seen to be isolated from its northern kin, but it is in contact with the lemon-scented gum *E. citriodora,* which in turn is in contact with *E. maculata. E. citriodora* has not reached its climatic limits and is probably an offshoot of *E. maculata,* of which it was for a long time regarded as a variety. *E. Torelliana* comes nearest to *E. maculata,* though no longer in actual contact with it except through *E. citriodora.* Possibly here, too, we have a case of loss of territory by a widespread species, as it is difficult to believe that *E. Torelliana* has descended from *E. maculata,* through *E. citriodora,* which is so unique in the nature of its oil.

E. Abergiana, the other coastal North Queensland endemic, has its nearest relative in *E. ptychocarpa,* a Kimberley and Northern Territory species, from which it is separated by several hundred miles of relatively dry country.

The Corymbosæ of the eastern coast, exclusive of Northern Queensland which has already been discussed, are *E. corymbosa, E. terminalis, E. dichromophloia, E. maculata, E. trachyphloia, E. intermedia, E. peltata, E. citriodora, E. Bloxsomei, E. eximia,* and *E. Watsoniana.* On their southern limit, as has been pointed out, temperature controls their range. *E. dichromophloia* and *E. trachyphloia* have been shown to have a distribution indicative of a dying out over wide areas. *E. eximia, E. peltata,* and *E. Watsoniana,* though closely related, are separated from one another. The remaining species along the coast are in contact with their relatives and do not show discontinuous distribution. They behave as would be expected, the wides occupying practically continuous stretches of territory, and here and there surrounding smaller areas of endemics.

The whole distribution of the Corymbosæ therefore indicates a former greater extension of the group throughout Australia. Lower temperature on the one hand and drier conditions on the other have forced the group from areas formerly occupied. The fossil evidence points either to their presence or the presence of allied forms formerly in Tasmania. At present the southern limit is one that is determined by temperature. Elsewhere in Australia the increasing dryness has left the three temperate Western Australian bloodwoods isolated from those of the rest of the continent. In the north and east the range of *E. dichromophloia, E. trachyphloia, E. Abergiana, E. peltata, E. Watsoniana,* and *E. eximia* suggests a fringe of relics on the margin of territory formerly peopled with bloodwoods. The larger numbers in the Kimberleys and the Northern Territory, and the fairly uniform distribution of species in the east and west except where the climate is unfavourable, the difference between eastern and northern on the one hand and western and southern on the other, would seem to indicate a former central concentration of the group. The occurrence of fossil bloodwood types in Tasmania shows that a retreat has taken place towards the north, and that the centre, though probably warm, was not necessarily located in that part of Australia which is tropical at the present day.

Eudesmieæ.

The Eudesmieæ, given generic rank by Robert Brown under the name of *Eudesmia*, and peculiar especially in the possession of calyx teeth, are widely spread in the warmer and drier parts of Australia. There are ten species, extending from the vicinity of Grafton northwards to Rockhampton, through western Queensland and northern Australia, the northern part of Central Australia, and down into the goldfields and wheat belt of Western Australia. *E. Baileyana*, which is found from Grafton to Rockhampton, is a temperate species, its isolated tropical locality, Dingo, being on the Blackdown Tableland. Its neighbour, *E. similis*, is not known to occur with it at the present day, and at their nearest point of approach they are about 200 miles apart, *E. similis* being found at Alice Downs in Central Queensland, a locality which is about that distance from the Blackdown Tableland. *E. lirata* from Bold Bluff in the Kimberleys is a close relative of both *E. similis* and *E. Baileyana*, and it is even more widely separated from them than they are from each other. Such a distribution indicates a loss of territory formerly occupied by the Eudesmieæ. In the west is *E. eudesmioides*, which occurs from the Mogumber River in Western Australia north and east to Tanami Goldfield and the Victoria River. It has given rise to *E. tetragona*, *E. erythrocorys*, *E. Ebbanoensis*, and *E. Merrickæ* in the wheat belt and gollfields of south-western Australia. *E. tetragona*, which is found east of Katanning in the Stirling Ranges, and at various localities round Hopetown and Ravensthorpe, does not make contact with the parent species or any of its near kin. It, too, furnishes a little further proof of the retrogression of the group.

In arid Northern Australia *E. eudesmioides* surrounds *E. odontocarpa*, and, applying the Age and Area hypothesis, this latter species is to be considered an offshoot from the widely spread one with which it is closely allied. Northwards, but isolated from these others, is *E. tetrodonta*, widely spread across Northern Australia from the Kimberleys to the Gulf, and, like *E. Baileyana*, occurring in regions of better rainfall, such as Melville Island. It surrounds the allied endemic *E. lirata* in the Kimberleys.

It appears, therefore, that the Eudesmieæ, though widely spread in Northern and Western Australia, are not of uniform distribution. Gaps separate the species from one another in the east, in the south-west, and in the north. They agree in general in being comparatively unsuccessful in the areas of better rainfall, *E. Baileyana* and *E. tetrodonta* being rather more successful than the others. These two, however, are not dominants in their formations. An ancient group, the Eudesmieæ have receded from much of their territory. The evidence, such as it is, of their origin seems to point to its being southern rather than extreme northern. *E. eudesmioides* and its probable offshoots, *odontocarpa, tetragona, erythrocorys, Ebbanoensis,* and *Merrickæ* are dry-country species mainly of temperate zone distribution, and those that are tropical do not push into the actual northern centres of Eucalypt population. *E. Baileyana* is temperate except for the outlying Blackdown Tableland locality, which climatically is not tropical. The three remaining species—*E. similis, E. tetrodonta,* and *E. lirata*—are well within the tropics. If the wide *E. tetrodonta* were the parent of *E. similis,* as it apparently was of *E. lirata,* it must formerly have had a distribution which it no longer possesses, unless it is *E. similis* which has contracted its boundaries.

The present distribution of the ten known species can best be accounted for by assuming that the group originally had a wide distribution in the milder parts of Central Australia when the region was better favoured as regards rainfall. With the increasing aridity it dwindled, the species at present fringing the original area occupied. Such a retreat has occurred with other plants such as the palms. Sir Baldwin Spencer (19) mentions the case of a small colony of palms in a gorge about two miles long in the Macdonnel Ranges, entirely isolated, but indicating a climate formerly very different from that of the present. The distribution of the Eudesmieæ is quite different from that of tropical groups, such as *E. alba* and its allies, which extend across the tropics continuously, the endemics occupying smaller areas in the territory covered by the wides.

EXTRA-AUSTRALIAN SPECIES.

No Eucalypts are found on the numerous oceanic islands which fringe the northern coastline, though on the continental islands (Fraser, Palm, Dunk, Magnetic, etc.) they are common where conditions of soil and rainfall are suitable. On Bathurst Island (north-west of Darwin) there is an endemic species (*E. Hillii*) not yet recorded from the mainland; otherwise the species on the islands are those found on the adjacent parts of the mainland. Only where the probability of land connection is great do we find such an extension of the Eucalypts to the islands. Guppy (20) found Eucalyptus fruits on the Valparaiso beaches, and cites them as an example of futile buoyancy; none of the species of the genus has become established naturally in Chile. The seeds have no chitinous coats like those of Acacia and are not adapted to saltwater transport. Maiden knows of no cases of mature seeds completing such a voyage, and points out that they fall out of the capsule readily after it has ripened. The genus extends beyond Australia through the northern islands as far as Mindanao in the Philippines. The gaps are wide in some cases. Four northern species are found in Papua—*E. alba, E. papuana, E. clavigera,* and *E. tereticornis. Eucalyptus alba* occurs in Australia from Gladstone northwards and across the north to the Kimberleys. In North Queensland it occurs with *E. tessellaris, E. terminalis,* and *E. tereticornis.* In the Kimberleys, according to Gardner, it occurs with *E. Spenceriana* and *E. miniata.* This is mentioned to show that some of the species which are its associates in Australia are not found in Papua. It is known also from

Timor and Flores with certainty, but has parted from the rest of the species there. *Eucalyptus papuana,* which was originally described from Papuan material, is found in Bathurst Island and in the Kimberleys. (The records of *E. tessellaris* for New Guinea, Northern Territory, and north-west Australia are doubtful, and the specimens are referable to *E. papuana.*) *E. clavigera* is found across northern Australia from Broome to the Gulf. In Papua it has been collected at Port Moresby and the Astrolabe Range. *E. tereticornis* is found from east Gippsland to Papua; in North Queensland it is mostly variety *latifolia,* and it is this variety that is found on the Northumberland Islands and in Papua.

In addition, there are two species, *E. Naudiniana* and *E. Schlecteri,* which are non-Australian. The former occurs along watercourses and in rain-forest country in Papua, New Britain, New Ireland, and the Philippines, and probably in the Moluccas and Celebes. It is closely related to *E. Schlecteri* from north-eastern Papua, an endemic species of narrow range. Other than this it has no close affinities, though there may be some distant connection with *E. Cloeziana,* which has a tropical and subtropical distribution in eastern Queensland.

These extra-Australian Eucalypts, though ranging in some cases far beyond this continent, are limited in so far as none of them cross Wallace's line (as revised by Merrill) on the west. Wallace's line as originally defined (21) ran between Bali and Lombok, between Borneo and Celebes, and south of the Philippine group. Merrill (22), from a consideration of the flora (especially the Dipterocarps) and the fauna, has modified the northern part so that the line now runs from between Celebes and Borneo northwards, cutting off Palawan from the rest of the Philippines. It thus corresponds with the margin of the Asiatic continental shelf. It is the western boundary of a zoogeographic and phytogeographic area intermediate in character between Malaysia and Papuasia. The eastern margin of this is known as Weber's line, which approximately coincides with the Australian continental shelf.

E. alba and *E. Naudiniana* have crossed Weber's line and are established in the unstable area between the Asiatic and Australian land masses. Such a distribution is made possible by the intermittent land connections which have existed from time to time in this archipelagic region, and which have facilitated the migration of other genera. A stream of Australian emigrants is represented by such genera as *Andropogon, Cladium, Centrolepis, Patersonia, Thysanotus, Drimys, Clianthus, Acacia* (*A. confusa,* a phyllodineous species), *Pleiogynium, Stackhousia, Halorrhagis, Pimelea,* etc. Merrill (23) considers that seven families and over five genera in the Philippines must be considered Australian types, and that their sparse distribution in Formosa, China, and south-eastern Asia indicates a long-continued separation of Luzon from the Asiatic mainland. That these types should have pushed northward to the Philippines rather than westward to Borneo, Java, and Sumatra is accounted for by the past geological history of the Malayan region. Between the Asiatic and Australian continental shelves lies an unstable archipelagic area with both flora and fauna intermediate between that of Western Malaysia and Papuasia. There is abundant evidence pointing towards the lack of direct land connections across this area linking east and west, though there have apparently been opportunities for migrations *viâ* the Philippines. Thus it happens that Australian plants find their way northward to the Philippines but may not be found in Java or Borneo. Merrill's work on the distribution of Dipterocarpaceæ, supported by a consideration of other constituents of the flora and also of the fauna, indicates that the Borneo-Mindanao connection which admitted this group from Western Malaysia was more extensive than the connection of Mindanao with Celebes or Gilolo, which also permitted migration towards New Guinea. It was at this period that the Australian types were enabled to reach the Philippines, and amongst them we have Eucalyptus. Merrill's conclusions as to the migrations of Dipterocarps are lent support by Diels's work (24) on the Papuan species of the family. Schlecter, too, finds that the orchids of the Celebes belong to the Papuasian region. The whole of the flora of the intermediate area of islands is a transition, and the modified lines of Wallace and Weber mark its boundaries.

A numerical comparison of Eucalypts in (*a*) North Australia from the Kimberleys across northern Australia to the Gulf of Carpentaria, (*b*) Papua and the New Britain archipelago, and (*c*) the transitional Timor-Celebes-Philippines zone, is as follows:—

TABLE 7.—COMPARISON OF EUCALYPTUS POPULATIONS AND ENDEMISM IN NORTHERN AUSTRALIA AND IN NON-AUSTRALIAN ISLANDS.

——	Endemics.	Wides.	Total.
North Australia	16	30	46
Papua and New Britain Archipelago	1	5	6
Intermediate Zone between East and West Malaysia	..	2	2

These areas are of approximately equal size, but even if only the country round the Gulf of Carpentaria is taken as representative of tropical Australia we still have three endemics and nineteen wides—a total of twenty-two. There is a very marked concentration in North Australia. In Papua where Eucalyptus formations exist, ecological conditions are similar to those of northern Australia where the same species occur in company with other species not found beyond the Commonwealth borders. None of the bloodwoods, on which so much argument has been based by various authors of papers on the origin of the Eucalypts, occur beyond Australia. *Eucalyptus alba* and *E. tereticornis* are species of very wide temperature toleration, and *E. clavigera* is also widely spread in northern Australia. *E. papuana*, also widely spread on the mainland, is closely related to *E. tessellaris*, which extends down into New South Wales. The far-flung distribution of these species in Australia indicates that, apart from having the power of spreading, they have also had time to do so; in other words, they are long-established species which, given the opportunity of pushing beyond Australia to the north, might be expected to do so. That endemic species related to them, or wides of more restricted range, have arisen in Australia and not in Papua, points to their Australian origin. *E. alba,* the species with the widest distribution (Australia to Papua, Timor, and Flores), has three Australian relatives of restricted range—*E. Houseana* in the Kimberleys and the Northern Territory; *E. populifolia* in the dry interior of New South Wales and Queensland; and *E. pallidifolia* in North Queensland and the Northern Territory. *Eucalyptus papuana* and *E. clavigera* belong to the Angophoroideæ with seven species—*E. papuana, E. clavigera, E. tessellaris, E. grandifolia, E. aspera, E. Spenceriana,* and *E. brachyandra* in Australia.

The other, with a mainland distribution, *E. tereticornis,* has Australian relatives of restricted distribution in *E. Bancrofti, E. amplifolia, E. exserta, E. Blakeleyi,* and in the south of the continent it grades off into *Eucalyptus rostrata.*

The non-Australian species *E. Naudiniana* and *E. Schlecteri* are a special case. *E. Naudiniana* (*E. deglupta*) is a dominant species along rivers and in dense forests in Papua, New Britain, New Ireland, and parts of Mindanao. *E. Schlecteri* is an endemic Papuan species described in 1922 by Diels from north-eastern Papua. Closely allied to *E. Naudiniana,* it is to be regarded as an offshoot from it. Taxonomically these two species are members of the Renantheræ, which reach their greatest development in temperate eastern Australia.

The other extra-Australian species are sclerophyllous forest types. Eucalyptus in the tropics usually fails under moist conditions, the Malayan element occupying the ground densely and excluding it. The dense rain forests are, as a rule, no place for the light-loving eucalypt, though in the more open monsoon forests in Northern Australia open forest types may occur. Columnar species, such as *E. saligna* and *E. Torelliana,* are more adapted to such habitats owing to their height and their rapid growth, and can compete to a certain extent with the tropical rain-forest types, though they mainly do so in the more open parts such as the forest margins and along streams.

In temperate Australia rain forests are often dominated by these columnar Eucalypts, as, for example, *E. regnans* and *E. goniocalyx* in Gippsland. *E. Naudiniana* is of this type, and is better adapted for the struggle in moist megathermic regions where the Malayan types are usually so much more successful. Its scattered distribution over the region from the Bismarck Archipelago westwards to Wallace's line shows that it has lost much territory which it must have once occupied, though still locally successful and dominant. One of the most striking characteristics of the forest formation of the wet region from Cardwell (North Queensland) north along the coast is the dominance of Malayan types over the Eucalypts, except in dry, sandy localities. Dense rain forest or monsoon forest occupies all but the driest parts of the area. On the forest floor where the light filters feebly through the dense canopy, only shade-loving species can survive. Brandis (25) has shown that in the case of *Shorea robusta,* and Brown (26) in the case of *Parashorea malaanonan,* that there is a pronounced suppression period in the early life of these types. Merrill considers that most Dipterocarps have this adaptation. In North Queensland rain and monsoon forests it is common to see numerous small plants belonging to the same species as the dominant tree types; while there are a few small trees of the same species. These small plants are apparently enduring a suppression period, and will ultimately die unless an opening occurs in the forest. During the 1926 cyclone in the Cairns district, such openings were torn in the forests, and within a few months the suppressed seedlings were shooting up rapidly.

In this district, where the conditions of temperature and rainfall are similar to those found throughout the greater part of the Malayan Islands, competition of this type suppresses the Eucalypts. Across the greater part of tropical Australia we have megathermic conditions combined with a fairly low rainfall, or even where the annual precipitation is fairly high, as at Darwin, its seasonal nature is very marked, and a long dry season prevents the appearance of rain forest. Here the Eucalypt becomes established. Twenty miles west of Cairns, where the rainfall suddenly diminishes as we come to the western slope of the divide, the rain forest disappears and Eucalypts take its place. Along the coastal plain of the dry belt south of Cardwell the same thing happens, though in the moist gullies the rain forest and monsoon forest reappears. In the temperate zone passing from dry country to the well-watered country of, say, Gippsland, we do not find the Eucalypts being suppressed in the same way. Tall, rapidly growing species such as *E. regnans, E. goniocalyx,* and *E. viminalis* dominate the temperate rain forests. In the tropics, under similar conditions of rainfall and soil moisture, the Malayan types would have ousted the autochthonous element.

For the most part the islands from the New Britain Archipelago to the west and north-west combine the two factors of high uniform temperature and abundant rainfall which have in the Cairns district suppressed the Eucalypts. The four Australian species, *E. tereticornis, E. alba, E. papuana,* and *E. clavigera,* which are found in this area are not of the tall shaft-trunked type, and prefer regions with a rainfall of 20 to 40 inches per annum. *E. tereticornis* is certainly fond of river banks, and therefore of moist conditions, but it must have plenty of light, and cannot compete with rain-forest types. *E. Naudiniana* is of the same growth form as *E. regnans* and other species common in temperate rain forests, and, while able to form pure formations along rivers, is also adapted to life in the rain forests. In this it is rather exceptional amongst tropical Eucalypts, and it is not surprising in the circumstances to find it as far north as Mindanao.

GENERAL.

Most of the conclusions reached by the study of the present distribution of the genus have been presented and discussed under the various sections of this paper. Some general remarks on the subject may now be made to summarise the conclusions from the evidence presented.

The fossil evidence shows that the Eucalypts with the transverse type of venation have receded from Tasmania. The temperature at the altitudinal limit of *E. corymbosa* on the mainland mountains is approximately that of the region where its southern outposts are found, so that it is temperature which is the present limiting factor in this case. During the last glacial period, when David (27) considers the snow-line to have come down fully 3,000 feet below the present level, the cold must have had a profound effect on the more southern bloodwoods. This difference in snow-line would indicate that the temperature conditions which now limit the progress of *E. corymbosa* southwards would have been somewhere about the latitude of Newcastle. *E. eximia,* which extends from Jervis Bay to Hornsby, and has been shown above to have reached its southern climatic limit, must either have occupied a more northern area at that time and have contracted its boundaries, or else be an endemic developed after the return of the bloodwoods at the close of the glacial period. Its present northern boundary is below the limit at which it could have existed at that time. The same remarks apply to *E. nowraensis,* a more southerly endemic of small range. The contraction of area from the edges, especially from the northern boundary, without any outlines to show a former northern extension, though possible, is not likely, and even more unlikely when the two endemic species show the same behaviour. A pre-glacial evacuation of the south, a post-glacial reinvasion, followed in the fulness of time by the development of these endemics, seems to have been the post-glacial history of this part of the Bloodwood group.

In the warmer parts of Australia low temperatures cease to restrict species. Here water supply is the deciding factor. Except in the case of a few species, *E. pyrophora* for example, the arid regions are unfavourable to bloodwoods. The distribution of the group round the borders of the continent is the result of the dying out of the group in the central regions as it became more arid. The committee on Quaternary Climates, appointed by the Australasian Association for the Advancement of Science, in its published report (28), summarises the knowledge on the subject. Some of this consists of deductions from present distribution of plants (based on the work of Cambage and of Andrews), and so cannot legitimately be used for explaining the distribution of the bloodwoods. Mammalian drift occurs in places and suggests a moist, if not wet, climate in the now arid interior, and a remarkable fauna of giant marsupials as the end of the Tertiary is pictured as being destroyed by the onset of arid conditions (29). The increasing aridity drove the bloodwoods to the edges of the continent, leaving the survivors to continue their existence within their temperature limits. That the group is not a dying one is amply evidenced by the number of endemics that have been produced, some of which have certainly not yet reached the limits of their possible range. Additional evidence of retreat is shown by the distribution of the Eudesmieæ and even by the eremean forms. In the favoured areas of the continent, development of the genus subsequent to the dying out of the central flora has proceeded along different lines in east and west. Cambage's excellent account of the development of the genus in New South Wales deals with the colonisation of the mountains after the Kosciusko uplift and the development of the flora of the western slopes. In Western Australia conditions have been fairly uniform, the uplifts being comparatively small and the restriction of marine deposits being strong negative evidence in favour of an ancient land surface (30). Here, too, there is geological evidence of increased aridity, but even without this the isolation of the south-western flora, and its definite relationships to the eastern, the survival of a few eremean Eucalypts of the same species in both east and west points to a former central Eucalypt population whose members gradually perished as they were subjected to increasing aridity.

The very wet regions in the tropics on the other hand are not favourable to the Eucalypts. The regions of heavy rainfall along the North Queensland coast, from between Cardwell and Innisfail northwards, are remarkable for the failure of the genus. Practically the whole of the territory is occupied by rain-forest types, and the few Eucalypts are on the drier ridges, the sandy stretches, and in a few cases in the more open parts of the rain forest where light conditions are more favourable.

A number of facts concerning the present distribution of the Eucalypts must therefore be taken into account when discussing the origin of the genus Eucalyptus. They are as follow:—

(1) The Eucalyptus flora of cold regions is specialised.

(2) The Eucalypts have retreated from regions now arid but formerly well watered.

(3) Greater numbers occur in the temperate arid zones than in the tropical arid zones.

(4) Eucalypts have failed in competition with rain-forest types in the tropical parts of Australia.

(5) The species in moderately well-watered regions of the tropics are few in comparison with those in similar areas in the temperate zone.

(6) The species which have both a tropical and a temperate distribution in eastern Australia indicate a southern origin rather than a northern.

(7) The Corymbosæ, often considered an unsuccessful type, though forced back with other types from the interior, have continued development in the coastal regions, though the Pleistocene glacial period destroyed them in the south. In southern New South Wales they are re-invaders, not a new type from the north.

(8) The geological and climatic history of Australia has been responsible for extensive dying of species of the genus, and the present barriers of climate and physiography (for example Bass Strait and the Great Divide) have so affected its spread that a simple application of the Age and Area hypothesis is impossible, except in small areas, and then only for a consideration of the local development of the genus.

In brief, it may be asserted that the drying up of Central Australia obliterated much of a well-developed Eucalypt population, leaving a marginal fringe of survivors. As the barriers of climate and physiography have changed considerably in the east, involving a northward retreat and a southward re-invasion, in addition to the retreat from the central regions, it is not possible now to locate the point of origin of the genus. In view, however, of its present-day requirements and of the reasons advanced, it seems certain that Eucalyptus first successfully established itself in that part of Australia which, in late Cretaceous or early Tertiary times, had a temperate climate and a fairly abundant rainfall.

SUMMARY.

Most of the species of Eucalyptus are located round the coast in a belt about 200 miles wide. Isolation of Tasmania and south-western Australia has resulted in a high proportion of endemism, the term "endemic" being used to denote a species restricted to one only of the defined regions. This high endemism is not a proof of great age. Most of the eastern Eucalypts are temperate, the total numbers and numbers of endemics decreasing north of Maryborough. Taking the whole of Australia, we have 30 species of narrow and 37 of wide range in the tropics, the figures for the temperate zone being 202 and 92 respectively. The number of species decreases rapidly as the arid regions are entered, and the endemism is also less marked except on the Western Australian goldfields, where the success of the *E. oleosa* and *E. incrassata* groups has raised the figures considerably. Eremean species such as *E. diversifolia, E. Flocktoniæ,* etc., which are found in east and west but not in central Australia, are regarded as relics. The bloodwoods are shown to be the descendants of a surviving fringe of forms which have retreated from the more central parts, and the same is true of the Eudesmieæ. Evidence is presented to show that there has been a retreat of the bloodwoods from the south, followed by a re-invasion from the north. The extra-Australian Eucalypts are emigrants, and the genus is a comparative failure in Malaysia owing to climatic factors. Present-day Eucalypts avoid the arid tropics, the extremely moist tropics, the arid temperate regions, and the cold of the mountain tops. In the favourable parts of the tropics their numbers are very small as compared with those of similarly watered temperate areas. It is concluded that the genus Eucalyptus at the present day is a development of the fringe of species which remained round the coast after the destruction of the greater number of the species as the central part of the continent became more arid, and that the early Eucalypts established themselves in the well-watered temperate portions of the continent.

REFERENCES.

(1) Maiden, J. H.—A Critical Revision of the Genus Eucalyptus, vol. i.-viii.

(2) Hooker, J. D.—Introductory Essay, Flora of Tasmania, 1860.

(3) Deane, H.—Presidential Address, Proc. Linn. Soc. N.S.W., x. (2), 619-667, 1896.

(4) Cambage, R. H.—Development and Distribution of the Genus Eucalyptus, Jour. & Proc. Roy. Soc. N.S.W., xlvii., 18-58, 1913; see also Proc. Linn. Soc. N.S.W., xlviii., 267-280, 1914.

(5) Cambage, R. H.—The Botanical and Chemical Characters of Eucalypts and their Correlation, B.A.A.S. (Manchester), 10-12, 1915.

(6) Andrews, E. C.—The Development of the Natural Order Myrtaceæ, Proc. Linn. Soc. N.S.W., xxxviii., 529-568, 1913.

(7) Unger, F.—New Holland in Europe, Jour. Bot., iii., 39, 1865.

(8) Ettingshausen, Baron C. von.—Cosmopolitan Flora of Tertiary Australia, Mem. Geol. Soc. N.S.W., 1888.

(9) Berry, E. W.—Eucalyptus never present in North America. Science, n.s. lxix., p. 91, Jan. 1919.

(10) Chapman, F.—A Sketch of the Geological History of Australian Plants: the Cainozoic Flora. Vict. Nat. xxxvii., Feb.-March 1921.

(11) Deane, H.—Presidential Address, Proc. Roy. Soc. N.S.W., xxi., 811-859, 1897.

(12) Jones, O. A.—The Tertiary Deposits of the Moreton District, S.E. Queensland. Proc. Roy. Soc. Qld., xxxviii., 23-46, 1926.

(13) Baker, R. T. and Smith, H. G.—Eucalypts and their Essential Oils—first edition Sydney, 1902; second edition Sydney, 1920.

(14) Hall, Cuthbert.—The Evolution of the Eucalypts in relation to the Cotyledons and Seedlings. Proc. Linn. Soc. N.S.W., xxxix., 473-532, 1914. (See also B.A.A.S., 1915, Manchester.)

(15) Willis, J. C.—Age and Area, 259 pp., Cambridge, 1922. (Also various papers in Annals of Botany, particularly vols. xxxi. to xxxvii.)

(16) Sinnott, Edmund W.—The Age and Area Hypothesis and the Problem of Endemism. Ann. Bot., xxxi., 209-216, 1917.

(17) Guppy, H. B.—The Testimony of the Endemic Species of the Canary Islands in favour of the Age and Area of Willis. Ann Bot., xxxv., 1921.

(18) Cambage, R. H.—Climatic and Geological Influences on the Flora of N.S.W. Aust. Asscn. Adv. Sc., xi., 437-483, 1907.

(19) Spencer, W. B.—Presidential Address, Aust. Asscn. Adv. Sc., liv. to lxxxix. (Hobart meeting), Melbourne, 1921.

(20) Guppy, H. B.—Observations of a Naturalist in the Pacific, vol. ii., p. 479, 1903.

(21) Wallace, A. R.—Island Life, 563 pp., third edition, 1911.

(22) Merrill, E. D.—Distribution of the Dipterocarpaceæ, Philippine Journ. Sci., xxiii., 1-34, 1923.

(23) Merrill, E. D.—Enumeration of Philippine Plants, Manila.

(24) Diels, L.—Die Dipterocarpaceen von Papuasien, Engl. Bot. Jahrb., lvii., 460-463, 1922.

(25) Brandis, D.—Journal Linn. Soc. (Bot.), xxxi., p. 6, 1895.

(26) Brown, W. H.—Vegetation of Philippine Mountains, Philippine Bureau of Science, Manila, 1919.

(27) David, T. W. E.—Geological Notes on Kosciusko, with special reference to evidences of Glacial Action. Proc. Linn. Soc. N.S.W., xxxiii., p. 648, 1908.

(28) Howchin, W.—Report of the Quaternary Climate Committee, Aust. Assen. Adv. Sci., xiv., 244-250, Melb. 1913.

(29) Jensen, H. I.—The Nature and Origin of the Gilgai Country. Proc. Roy. Soc. N.S.W., xlv., p. 347, 1911.

(30) Jutson, J. T.—An Outline of the Physiographical Geology of W. Aust. Bull. 61, Geol. Survey of W.A., 1914.

The Royal Society of Queensland.

Report of Council for 1927.

To the Members of the Royal Society of Queensland.

Your Council has pleasure in submitting its Report for the year 1927.

Ten original papers were read and discussed before the Society during the year. Two public meetings of a popular character were held. Professor B. D. Steele, D.Sc., F.R.S., gave a lecture on "Oil in Queensland," and on the occasion of the Newton Tercentenary addresses were delivered by Professors T. Parnell, H. J. Priestley, and Mr. H. A. Longman. During the year Professor E. J. Goddard gave a lecturette on "Bunchy Top of the Banana."

The Council wishes to acknowledge generous subsidies amounting to £104 19s. from the Queensland Government towards the cost of printing the Proceedings of the Society. Appreciative acknowledgment is also expressed to the University of Queensland for housing the library and providing accommodation for meetings. The library has been removed to a room adjacent to the University library, and has been reorganised.

The membership roll consists of four corresponding members, six life members, 173 ordinary members, and three associates. During the year ten new members were elected. The deaths of Professors Liversidge and Rennie (corresponding members) and Dr. W. F. Taylor (a trustee) are reported with regret. Messrs. F. Bennett, B.Sc., and J. B. Henderson, F.I.C., and Dr. A. J. Turner were elected Trustees of the Society.

There were ten meetings of the Council. The attendance was as follows:—E. W. Bick 10, W. H. Bryan 7, J. V. Duhig 5, E. J. Goddard 7, R. W. Hawken 5, D. A. Herbert 9, H. A. Longman 3, E. O. Marks 9, T. Parnell 8, H. C. Richards 7, C. T. White 8.

E. J. GODDARD, President.

D. A. HERBERT, Hon. Secretary.

THE ROYAL SOCIETY OF QUEENSLAND.

Cr. STATEMENT OF RECEIPTS AND EXPENDITURE FOR YEAR ENDED 31st DECEMBER, 1927. **Dr.**

Receipts.	£	s.	d.
Bank Balance, 31st December, 1926	3	11	3
Subscriptions	170	2	0
Government Subsidy, on Printing Account	104	19	0
Sale of Reprints and Volumes, Proceedings	6	15	0
Exchanges	0	9	0
	£285	16	3

Expenditure.	£	s.	d.
Government Printer—			
Volume and Abstracts	209	18	0
Stationery Account	4	15	0
State Government Insurance	0	13	0
Hon. Secretaries (Postages)	12	17	10
Hon. Librarian (Postages)	4	0	0
Hon. Treasurer (Postage and Duty Stamps)	2	0	0
Lanternist (C. Illidge)	1	0	0
Advertising	3	3	9
Labour (Rearranging Library)	10	0	0
Minute Book	0	7	6
Exchanges and Stamps (Duty)	0	10	8
Bank Charges	0	10	0
Balance in Bank, 31st December, 1927	36	0	6
	£285	16	3

Examined and found correct.
H. J. PRIESTLEY, Hon. Auditor,
25th February, 1928.

E. W. BICK, Hon. Treasurer.

Abstract of Proceedings, 19th March, 1928.

Special Meeting.

A Special Meeting was held in the Geology Lecture Theatre of the University at 7.40 p.m. on Monday, 19th March. The President, Professor E. J. Goddard, occupied the chair. On the motion of Mr. Longman, seconded by Dr. Marks, it was decided that Rule 15 of the Constitution of the Society be altered to allow of the appointment of two editors instead of one.

Annual Meeting.

The Annual Meeting of the Society was held in the Geology Lecture Theatre of the University at 8 p.m. on Monday, 19th March, 1928.

His Excellency the Governor, Sir John Goodwin, occupied the chair.

Apologies were received from Mr. G. H. Barker and Dr. Hamlyn Harris.

The Minutes of the previous meeting were read and confirmed.

The Annual Report and Financial Statement were adopted.

The following officers were elected for 1928:—

President: Professor T. Parnell, M.A.

Vice-Presidents: Professor E. J. Goddard, B.A., D.Sc. (*ex officio*), and Professor J. P. Lowson, M.A., M.D.

Hon. Secretary: Mr. D. A. Herbert, M.Sc.

Hon. Librarian: Dr. J. V. Duhig, M.B.

Hon. Treasurer: Mr. E. W. Bick.

Hon. Editor: Mr. H. A. Longman, F.L.S., C.M.Z.S.

Hon. Auditor: Professor H. J. Priestley, M.A.

Members of Council: Professor R. W. Hawken, B.A., M.E., M. Inst. C.E., Dr. T. G. H. Jones, A.A.C.I., Dr. E. O. Marks, B.A., B.E., M.D., Professor H. C. Richards, D.Sc., and Mr. C. T. White, F.L.S.

Dr. O. S. Hirschfeld was unanimously elected as an ordinary member.

Mr. T. A. Williams and Mr. W. W. Bryan were proposed for ordinary membership.

Professor T. Parnell was inducted to the position of President for 1928, and Professor E. J. Goddard delivered his Presidential Address entitled "Virus Diseases: Their Bearing on the Cell Theory and other Biological Concepts." On the motion of Mr. H. A. Longman, seconded by Dr. J. V. Duhig, a vote of thanks was accorded the retiring president for his address. A vote of thanks to His Excellency the Governor was carried on the motion of Professor H. C. Richards, seconded by Mr. J. B. Henderson.

The Council has received a letter from Dr. E. O. Marks, Hon. Secretary, Great Barrier Reef Committee, University, Brisbane, and, as this is of special interest, it is communicated for the information of members who may desire to co-operate.

Dear Sir,

In reference to the expedition to the Great Barrier Reef which is expected to arrive from England in July and which has the full support and co-operation of this Committee, I am directed to enclose copy of a memorandum containing the latest details to hand.

Both the English Committee and the leader of the expedition, Dr. Yonge, have repeatedly expressed their desire for the co-operation of Australian workers in marine biology. Unfortunately the funds will not permit of offering any salary. It is hoped by this Committee, however, that the unique opportunity for combined scientific work will be taken advantage of by research workers and institutions interested in marine biology. My Committee would be glad to hear if your institution desires to send a representative to work in conjunction with the expedition or can recommend any research student or other worker who may be desirous of joining the expedition.

Yours faithfully,

E. O. MARKS, Hon. Secretary.

To the Hon. Secretary,
Royal Society of Queensland.

Addendum.—In accordance with the alteration to rule 15, made at the special meeting on 19th March, 1928, Dr. W. H. Bryan, M.C., was appointed co-editor by the Council of the Society.

D. A. HERBERT, Hon. Secretary.

Abstract of Proceedings, 30th April, 1928.

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre on Monday, 30th April, 1928, at 8 p.m.

The President, Professor T. Parnell, in the chair, and about forty members present.

An apology for absence was received from Mr. C. T. White.

The minutes of the previous meeting were read and confirmed.

Messrs. T. A. Williams and W. W. Bryan were elected ordinary members of the Society.

Messrs. W. J. Chamberlain, M.Sc., Inigo Jones, and T. Rimmer, M.Sc., were nominated for ordinary membership.

A paper entitled "*Cinnamomum Laubatii*—The Chemical Characters of the Essential Oils of Leaves and Bark," by T. G. H. Jones, D.Sc., A.A.C.I., and F. B. Smith, B.Sc., F.I.C., was read by Dr. Jones, and commented on by Professor H. C. Richards and Messrs. Herbert and Henderson.

Dr. J. V. Duhig read a paper on "Investigations into Sewage Pollution of the Brisbane Estuary." As the result of investigations over the period of five months, he reached the following conclusions:—

(1) The present method of disposal of sewage into the Brisbane River estuary is not a nuisance.

(2) The sewage as discharged contains solid matter only in a very finely divided state.

(3) The bacterial content of the sewage is reduced with very great rapidity.

(4) The power of the water of the Brisbane estuary to render sewage innocuous at present is many multiples of its used power in this respect.

(5) The volume of water in the Brisbane estuary can effectually sterilise, at a minimum twenty-four hours, effluent within the time estimated at four hours from cessation of discharge at the outfall, even at a maximum depth of 4 feet of water.

(6) Shallow water is not as good a diluent for sewage as deep water.

(7) Onshore winds blowing on shallow water hinder dispersion and dilution.

(8) Sewage disposal would be greatly improved by continuation of the outfall into deeper water. The optional length of this continuation would be a function of the grade of the channel, and could only be determined by sounding experiments.

(9) At present the method of disposal is economically sound and perfectly safe, provided that no sea food is taken from the shore 800 yards above and below the outfall sewer, at a distance of 50 yards from high-water mark.

(10) The most perfect hygienic result can be obtained by sewage discharge lasting from the end of flood tide until within an hour of the end of the ebb tide.

(11) All these conclusions may be altered by large increases in the volume of the discharge.

The paper was discussed by Professor Hawken and Messrs. Henderson and Longman, and the President.

Mr. S. B. Watkins exhibited a fasciated rose stem which, on pruning, had given rise to normal shoots.

Mr. H. A. Longman exhibited a cast of the fossil Galilee skull, the original of which was found in a cave near the Lake of Galilee in 1925, and was the first skull of the Neanderthal type to be found outside Europe. The Galilee skull consists of the frontal part of the brain-case, with incomplete facial bones. The skull was narrow and high-vaulted, and the bones were not so thick as in characteristic Neanderthal fossils. In some respects this fossil approaches the Australian aboriginal.

Mr. H. Tryon commented on the exhibit.

Mr. D. A. Herbert exhibited specimens of haustoria of *Exocarpus humifusa,* a Tasmanian hemi-parasitic flowering plant. The specimens were collected for the first time in National Park, Tasmania, in January, 1928.

Abstract of Proceedings, 28th May, 1928.

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre of the University on Monday, 28th May, 1928, at 8 p.m.

The President, Professor T. Parnell, in the chair, and fourteen members present. Apologies for non-attendance were received from His Excellency the Governor, Dr. J. V. Duhig, and Mr. D. A. Herbert.

Messrs. W. J. Chamberlain, M.Sc., Inigo Jones, and T. Rimmer M.Sc., were elected ordinary members of the Society.

Mr. F. W. Moorhouse, B.Sc., was nominated for ordinary membership by Mr. D. A. Herbert, and Mr. R. C. Cowley by Dr. J. V. Duhig.

Mr. A. P. Dodd, in a few introductory remarks, tabled a paper on the "Revision of Four Genera of Scelionidæ."

Mr. A. P. Dodd also delivered a very interesting lecture on "Prickly-pear Insects." In outlining the subject he pointed out that the Prickly-pears (*Opuntia* spp.) had been introduced into Australia without their natural enemies. Owing to this, and to favourable climatic conditions, they had spread rapidly and become a pest. In their native habitats, Southern North America and South America, the various forms of prickly-pear were kept in check by natural enemies in the shape of insect pests.

The Prickly-pear Board has concentrated its activities on investigating insects adversely affecting the pear and on introducing those found the most effective. On arrival they are carefully tested by laboratory and field experiments, to ascertain whether they will attack economic or other plants as well as members of the Opuntia family.

Mr. Dodd gave an interesting review of the introduction, breeding, testing and liberation of insects, and he stated that so far the Indian cochineal and cactoblastus had proved the most effective, and with the aid of these insects the prickly-pear was now held in check from spreading, and there is every probability of its gradual extermination.

Mr. C. T. White, in proposing a vote of thanks to the lecturer, paid a tribute to the good work being carried on by Mr. Dodd and his staff. Mr. J. B. Henderson, in seconding the motion, outlined the events leading to the formation of the Prickly-pear Board, and gave instances of the very effective work of pear destruction.

ABSTRACT OF PROCEEDINGS, 25TH JUNE, 1928.

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre of the University on Monday, 25th June, 1928, at 8 p.m.

The President, Professor T. Parnell, in the chair, and eighteen members present. Apologies for non-attendance were received from His Excellency the Governor, Professor Richards, Dr. Whitehouse, and Mr. Tryon.

Messrs. F. W. Moorhouse, B.Sc., and R. C. Cowley were elected ordinary members of the Society. Mr. L. L. S. Barr was nominated for ordinary membership by Mr. W. C. Dormer, and Dr. John Bostock, M.B., B.S., D.P.M., M.R.C.S., L.R.C.P., by Mr. H. A. Longman.

The President announced that at a special meeting to be held on 16th July Sir Arnold Theiler would deliver a lecture on "Problems of Phosphorus Deficiency in Stock."

Mr. W. D. Francis read a paper entitled "The Location of Saponin in the Foam-Bark Tree (*Jagera pseudo-rhus*)." The bark of the foam-bark tree was a commercial commodity in Australia before the war. It was used as a substitute for quillaja bark which produces a head or foam on cordials. The foam-bark tree is found in the scrubs or rain forests of the coastal part of Australia from the Richmond River in New South Wales to the Barron River, North Queensland. The frothing of infusions of the bark is due to saponin. As a result of anatomical and micro-chemical studies of the various parts of the tree the investigator found saponin to be concentrated in certain parts of the outer bark of the stem and root, in the wood of very young twigs, in the walls of the fruit, and in the recently-formed wood of the root and stem. The chlorophyll-containing tissue of the leaves do not contain saponin, and it is therefore indicated that the saponin is not a direct product of photosynthesis. The concentration of saponin in the cell walls in almost all cases suggests that it is concerned with the construction or composition of the cell walls. The frequent occurrence of saponin in association with hardened tissue suggests that it may be especially connected with the elaboration of woody tissue. The paper was discussed by Messrs. Dormer, Bennett, White, and Longman.

A paper by G. H. Hardy entitled "Revisional Notes on Described Australian Robberflies of the Genus *Ommatius*," was communicated by the Hon. Secretary. The paper was accompanied by specimens referred to in the text.

Mr. C. T. White exhibited specimens of 32 species of Basidiomycetes, mostly Polyporaceæ, collected on Dunk Island by Mr. W. C. Dormer in May, 1927. As some of these have not hitherto been reported from the State, it is intended to publish the list.

Mr. H. A. Longman exhibited (*a*) fossil Dicotyledonous leaves from Mr. A. Arthur's property, Coolabunia, seven miles from Kingaroy; and (*b*) two molar teeth and the fragment of a mandible of *Macropus anak* found 40 feet below the surface in a well by Mr. D. Salisbury at Knapp's Creek, near Beaudesert. The exhibits were discussed by Dr. W. H. Bryan and Dr. George Parker.

Abstract of Proceedings, 27th August, 1928.

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre on Monday, 27th August, 1928, at 8 p.m.

The President, Professor T. Parnell, in the chair, and about thirty members present.

The Minutes of the previous meeting were read and confirmed. Mr. L. L. S. Barr and Dr. John Bostock, M.B., B.S., D.P.M., M.R.C.S., L.R.C.P., were elected ordinary members of the Society.

The President referred to the death of Mr. W. R. Colledge, and expressed the Society's appreciation of his work.

Professor H. C. Richards communicated a paper entitled "A Geological Reconnaissance of Part of the Aitape District, Mandated Territory of New Guinea," by H. G. Raggatt, B.Sc., of the Department of Mines, Sydney. The general geographical features of the area are as follow: (1) The Coastal plain is about one mile wide at Ulau, and reaches a maximum of approximately 12 miles at Sissano. It is so little raised that the streams which flow through it inevitably meander as they approach the sea, in some places forming deltas with numerous distributaries. With the exception of Vanimo, there are no deep water bays of importance. (2) The Coastal foothills are a well-defined area between the plain and the main dividing range, and have an average height of about 500 feet. The streams are relatively swift flowing and deeply entrenched. (3) The Dividing Range here does not exceed 5,000 feet in height and is enclosed in thick jungle. (4) The Inland slopes, populated by the Wa-pi tribe, are little known.

The rocks exposed were provisionally classified. They include pre-Cretaceous schists and gneisses of the main dividing range; pre-Miocene (possibly Mezozoic) altered sediments; Tertiary (probably Miocene) beds of blue micaceous mudstone alternating with shale and sandstone, and of limestone; late Tertiary (probably Pliocene) beds of limestone, volcanic rocks, conglomerate, sandstone, and agglomerate; recent and Pleistocene estuarine and river beds, river gravels, sands, and muds. Palæontological notes were supplied by Messrs. Tom Iredale and W. S. Dun. It was suggested that the search for oil be confined in the first place to locating suitable structures in beds of Miocene age which have not been too highly folded or much intruded by igneous rocks. The paper was discussed by Sir Edgeworth David, Mr. J. H. Reid, and Dr. E. O. Marks.

Professor H. C. Richards exhibited a specimen of clay shale with a curious chocolate iron-staining pattern. The specimen, which was forwarded by Mr. T. Blatchford, the Government Geologist of Western Australia, has a very unusual pattern which, owing to its regularity and nature, suggests a possible organic origin. It came from a locality 80 miles south-east of Wyndham, Western Australia, and underlies the Salterella beds. Mr. Blatchford has obtained other specimens of similar pattern in the Braeside area from the Nullagine series. The finder is anxious to have an adequate explanation of the origin of the pattern, and hopes that such may possibly help in fixing the age of the Nullagine beds more accurately.

Professor Richards also exhibited precious opal from a quarry in the Brisbane tuff at Kedron. This was forwarded by Mr. Huxham, an engineer of the Brisbane City Council, and had been obtained during quarrying operations from " porphyry " metal. The exhibits were commented on by Dr. Bryan, and an informal discussion took place.

The Council wishes to draw the attention of members of the Society to an announcement by the Royal Society of New South Wales that a prize, known as " The Walter Burfitt Prize," has been established by that Society. The prize is awarded at intervals of three years to the worker in pure or applied science, resident in Australia or New Zealand, whose papers and other contributions published during the past three years are deemed of the highest scientific merit, account being taken only of investigations described for the first time, and carried out by the author mainly in these Dominions. The prize consists of a medal and the sum of £50, and may be awarded to two authors working in collaboration. The first award will be made in May, 1929, and nominations and publications should be submitted to the Royal Society of New South Wales not later than 28th February, 1929.

D. A. HERBERT,
Hon. Secretary.

Abstract of Proceedings, 24th September, 1928.

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre of the University on Monday, 24th September, 1928, at 8 p.m.

The President, Professor T. Parnell, in the chair, and about forty members present.

The minutes of the previous meeting were read and confirmed. Miss M. E. Lethbridge was nominated for ordinary membership by Dr. J. V. Duhig.

Professor R. W. Hawken, B.E., read a paper on "Stress Transmission in Frictional-cohesive Material." This was an inquiry into the question of stress transmission in material other than fluids. Fluid pressure was taken as the fundamental law, and the change in stress throughout the material arising from potential frictional and cohesive resistance to shear, separately and conjointly, were expounded. The author's method goes on the assumption that the cohesive resistance is independent of previously existing stress equilibrium for non-cohesive material. Consequently, in computation cohesion is treated as an independent shear introduced as a maximum on a plane with corresponding shears on all other planes. The plane on which the shear c is introduced will be the Critical Plane of Equilibrium. In the ellipse of stress deduced, the active shear on the critical plane is equilibrated by the potential resistance to shear due to both frictional and cohesive resistance. The outstanding factor of the analysis set out is that the principal planes for frictional-cohesive material differ necessarily in direction from those for the same loading, presuming no cohesion. In the author's view, the theories of Rankine (earth pressure), of Navier (failure in compression), and of Guest (failure by shear) are special limiting cases. Those of Scheffler (unsupported banks), Ketchum (trench cutting), Bell (pressure in clay), and any straight line wedge theory for cohesive material have the same basic error—namely, that a limiting condition, impossible practically, is assumed as existing for the general case. The author's view being at variance with accepted theories, the reasons were discussed from several aspects and illustrated by examples, theoretical and practical. The paper was commented on by the President and by Dr. E. O. Marks.

Dr. R. Hamlyn-Harris read a paper entitled "Notes on the Breeding Habits of *Culex fatigans*, Wied., and its Associated Mosquitoes in Queensland." *C. fatigans* is found associated with nine different species of mosquito in the Greater Brisbane area, the association being dependent to a very large extent upon the state of the water at the time of selection. There exist cyclic variations due to rain and atmospheric conditions in which temperature and humidity play an important part. The study of hydrogen ion concentration within certain limits of waters selected for breeding purposes does not throw any light on the reason for selection, but serves only as an indication of the type of water preferred by certain kinds of foodstuffs or organisms or aquatic vegetation, as the case may be. There is considerable mortality among the developmental stages of *C. fatigans* at all times, but especially during hot summer weather. It is surmised that this is due either to a kind of intoxication or narcotic poisoning, or to the toxic nature of the decomposition products, especially in· aced by the high temperature. Investigations into the breeding of mosquitoes in the Brisbane cemeteries lead to the belief that *C. fatigans* and *Aedes notoscriptus* choose the artificial receptacles on graves more so than other mosquitoes and use them to the full extent of their power. *C. fatigans* holds undivided sway in some cemeteries, *A. argenteus* choosing vessels near human habitations for preference. It is surmised that *Mucidus alternans* and *Aedes vigilax* select fresh water only from compulsion, being both by nature salt marsh mosquitoes. Charophyta do not thrive in pollution, and hence when mosquito larvæ occur with *Nitella* they are usually *A. annulipes*, and sometimes other sylvan species rather than *C. fatigans*. Under laboratory conditions, however, it is quite a common thing for *C. fatigans* to lay egg rafts upon *Nitella* water. The size of the egg rafts of *C. fatigans* is entirely dependent upon the state of maturity of the female. Though the presence of food seems to be the determining factor in the selection of breeding places, the quantity and quality of the decomposition products in the water may be said to be the main determining factors with regard to the measure of retardation in development of *C. fatigans*.

Under laboratory conditions eggs sometimes fail to produce larvæ, and it is surmised that infertile females, even though possibly fed on blood, produce infertile eggs. The possibility of the septic tank as a breeding ground for *C. fatigans* must be recognised. Pollution from tanneries is responsible for enormous numbers of *C. fatigans*, though tan liquor pits are far too acid for selection. The paper was discussed by

Dr. J. V. Duhig, Mr. F. A. Perkins, Dr. E. O. Marks, and Mr. W. J. Chamberlain.

A paper entitled "The Essential Oil of *Eucalyptus Andrewsi* from Queensland," by T. G. H. Jones, D.Sc., A.A.C.I., and M. White, B.Sc., was laid on the table. A eucalypt common on the road between Toowoomba and Crow's Nest, named by Mr. C. T. White as *E. hæmastoma* var. *inophloia*, but considered by him as probably referable to *E. Andrewsi*, was shown on the evidence of its essential oil to belong to the latter species.

Abstract of Proceedings, 29th October, 1928.

The Ordinary Monthly Meeting was held on 29th October, 1928, at 8 p.m., in the Geology Lecture Theatre, University. The President, Professor T. Parnell, in the chair, and about twenty-five members present. Apologies were received from Dr. Marks and Professor Richards.

The minutes of the previous meeting were read and confirmed. Miss M. E. Lethbridge was elected to ordinary membership of the Society. A paper entitled "Petroleum from the Roma Bores," by J. B. Henderson, F.I.C., and W. J. Wiley, M.Sc., was communicated by the senior author. This was an account of the work undertaken at the Government Chemical Laboratory, and an historical account of the investigations was given. The experimental work on a sample of Roma oil received in November 1927 involved a fractional distillation of the oil, and the determination of the vapour pressure, vapour density, and specific gravity of the fractions. The results were presented in tabular form, and samples exhibited. Dr. L. S. Bagster, Mr. Reid, and the President discussed the paper.

Dr. W. H. Bryan communicated a paper by Mrs. C. Briggs on "The Brisbane Tuff." The paper dealt in some detail with the field occurrence and petrological characters of that formation. Chemical analyses of typical samples of the tuff were given and compared with chemically similar rocks in Australia and elsewhere. The age and origin of the Brisbane tuff were fully discussed, and a hypothesis was advanced as to its relationship with the various late Palæozoic and Mezozoic igneous rocks of Southern Queensland. The economic value of the formation was also considered. Messrs. Denmead and Inigo Jones and Dr. Bryan discussed the paper, and appreciative comment was made by letter by Professor Richards.

Abstract of Proceedings, 26th November, 1928.

The ordinary monthly meeting was held in the Geology Lecture Theatre of the University on Monday, 26th November, 1928, at 8 p.m.

The President, Professor T. Parnell, in the chair and twenty members present.

The minutes of the previous meeting were read and confirmed.

Mr. D. A. Herbert, M.Sc., read a paper entitled "The Major Factors in the Present Distribution of the Genus Eucalyptus." Most of the species of Eucalyptus are located round the coast in a belt about 200 miles wide. Isolation of Tasmania and south-western Australia has resulted in a high proportion of endemism. This high endemism is not a proof of great age. Most of the eastern eucalypts are temperate, the total numbers and numbers of endemics decreasing north of Maryborough. Taking the whole of Australia, there are 30 species of narrow and 37 of wide range in the tropics, the figures for the temperate zone being 202 and 92 respectively. The number of species decreases rapidly as the arid regions are entered, and the endemism is also less marked except on the Western Australian goldfields, where the success of the *E. oleosa* and *E. incrassata* groups has raised the figures considerably. Eremean species such as *E. diversifolia, E. Floctoniæ,* etc., which are found in east and west but not in central Australia, are regarded as relics. The bloodwoods were shown to be the descendants of a surviving fringe of forms which have retreated from the more central parts, and the same is true of the Eudesmieæ. Evidence was presented to show that there has been a retreat of the bloodwoods from the south, followed by a re-invasion from the north. The extra-Australian eucalypts are emigrants, and the genus is a comparative failure in Malaysia owing to climatic factors. Present-day eucalypts avoid the arid tropics, the extremely moist tropics, the arid temperate regions, and the cold of the mountain tops. In the favourable parts of the tropics their numbers are very small as compared with those of similarly watered temperate areas. It is concluded that the genus Eucalyptus at the present day is a development of the fringe of species which remained round the coast after the destruction of the greater number of the species as the central part of the continent became more arid, and that the early eucalypts established themselves in the well-watered temperate portions of the continent. The paper was discussed by Messrs. C. T. White, W. D. Francis, and Inigo Jones.

Mr. H. A. Longman exhibited a juvenile specimen of *Epiceratodus forsteri,* 145 mm. in length, which was one of a series secured alive from Enoggera Reservoir. The discovery of these juvenile lung-fishes was of interest to members, as they were the progeny of the large specimens placed in the reservoir in 1895-1896 by the late D. O'Connor under the auspices of the Royal Society of Queensland. A detailed report appears in "Memoirs of the Queensland Museum," vol. ix., part 2, pp. 160-173.

Publications have been received from the following Institutions, Societies, etc., and are hereby gratefully acknowledged.

AFRICA.

ALGERIA—

Société de Géographie et d'Archéologie d'Oran, Oran.

UNION OF SOUTH AFRICA—

Durban Museum, Natal.

South African Museum, Capetown, Cape Province.

Transvaal Museum, Pretoria.

Geological Society of South Africa, Johannesburg.

AMERICA.

ARGENTINE—

Museo de la Plata, Universidad Nacional de la Plata.

BRAZIL—

Instituto Oswaldo Cruz, Rio de Janeiro.

Ministerio de Agricultura, Industria y Commercio, Rio de Janeiro.

CANADA—

Department of Agriculture, Ottawa.

Department of Mines, Ottawa.

Royal Society of Canada, Ottawa.

Royal Astronomical Society of Canada, Toronto.

Royal Canadian Institute, Toronto.

Nova Scotia Institute of Science, Halifax, Nova Scotia.

UNITED STATES OF AMERICA—

Bingham Oceanographic Institute, San Diego.

Florida Geographical Society.

Carnegie Institution, Washington.

Library of Congress, Washington.

National Academy of Sciences, Washington.

National Research Council, Washington.

Smithsonian Institution, Washington.

United States Department of Agriculture.

United States Department of Commerce (Bureau of Standards), Washington.

United States Department of the Interior (United States Geological Survey), Washington.

United States National Museum, Washington.

United States Treasury (Public Health Service).

Lawde Observatory, Arizona.

University of California and Scripps Institute, Berkeley, California.

John Hopkins University (Institute of Biological Research), Baltimore.

American Academy of Arts and Sciences, Boston.

Boston Society of Natural History, Boston.

Buffalo Society of Natural Science, Buffalo.

John Crerar Library, Chicago.

Field Museum of Natural History, Chicago.

Lloyd Library, Cincinnati.

Ohio Academy of Science, Columbus.

Ohio State University, Columbus.

Bernice Pauahi Bishop Museum, Honolulu.

Natural History Survey, State of Illinois.

Indiana Acadamy of Science, Indianapolis.

Cornell University, Ithaca, N.Y.

Cornell University Agricultural Experiment Station.

Arnold Arboretum, Jamacia Plain, Penn.

Wisconsin Academy of Arts, Science, and Letters, Madison.

Michigan Academy of Arts, Science, and Letters, Michigan.

University of Michigan, Michigan.

Minnesota Geological Survey, Minneapolis.

University of Minnesota, Minneapolis.

New York Academy of Sciences, New York.

American Geographical Society, New York.

American Museum of Natural History, New York.

Bingham Oceanographic Collection, New York.

New York Zoological Society, New York.

Oberlin College, Ohio.

Academy of Natural Sciences, Philadelphia.

American Philosophical Society, Philadelphia.

Portland Society of Natural History.

Rochester Academy of Science, Rochester.

San Diego Society of Natural History, San Diego.

California Academy of Sciences, San Francisco.

Puget Sound Biological Station, Seattle.

Missouri Botanic Garden, St. Louis.

University of Illinois, Urbana.

MEXICO—

Instituto Geologico de Mexico, Mexico.

MEXICO—*continued.*

Sociedad Cientifica, "Antonio Alzate," Mexico.

Observatorio Meteorologico Central, Tacaibaya, D.F., Mexico.

Secretario de Agricultura y fomento, Mexico.

ASIA.

CEYLON—

Colombo Museum, Colombo.

INDIA—

Agricultural Research Institute, Pusa.

Government of India—

Department of Agriculture.

Geological Survey.

Superintendent, Government Printing.

Punjab University.

Indian Academy of Science.

JAPAN—

Imperial University, Kyoto.

Imperial University, Tokyo.

National Research Council of Japan, Tokyo.

JAVA—

Koninklijke Naturkundige, Batavia.

Department van Landbouw, Buitenzorg.

PHILIPPINE ISLANDS—

Bureau of Science, Manila.

College of Agriculture, University of the Philippines, Manila.

AUSTRALIA AND NEW ZEALAND.

COMMONWEALTH—

Australian Commonwealth Engineering Standards Association, Melbourne.

Commonwealth Department of Health, Melbourne.

Commonwealth Institute of Science and Industry, Melbourne.

QUEENSLAND—

Department of Agriculture, Brisbane.

Department of Mines, Brisbane.

Queensland Geological Survey, Brisbane.

Queensland Museum, Brisbane.

Queensland Naturalists' Club, Brisbane.

Royal Geographical Society of Australasia (Queensland), Brisbane.

State Statistician, Brisbane.

NEW SOUTH WALES—

Australasian Association for the Advancement of Science, Sydney.

Department of Agriculture, N.S.W.

Botanic Gardens, Sydney.

Geological Survey of N.S.W., Sydney.

Public Library, Sydney.

Linnean Society of N.S.W., Sydney.

Australian Museum, Sydney.

Royal Society of New South Wales, Sydney

Naturalists' Society of N.S.W., Sydney.

University of Sydney.

VICTORIA—

Bureau of Census and Statistics, Melbourne.

Royal Society of Victoria, Melbourne.

Field Naturalists' Club, Melbourne.

Department of Agriculture, Melbourne.

Department of Mines, Melbourne.

Australasian Institute of Mining and Metallurgy, Melbourne.

Australian Veterinary Association, Melbourne.

TASMANIA—

Royal Society of Tasmania, Hobart.

Field Naturalists' Club, Hobart, Tasmania.

Geological Survey of Tasmania.

SOUTH AUSTRALIA—

Royal Society of South Australia, Adelaide.

Royal Geographical Society of S.A., Adel.

National Museum of South Australia, Adel.

Geological Survey of S. Australia, Adel.

Public Library, Museum, and Art Gallery, Adel.

University of Adelaide.

WESTERN AUSTRALIA—

Royal Society of Western Australia, Perth.

Geological Survey of Western Australia, Perth.

NEW ZEALAND—

Auckland Institute, Auckland.

New Zealand Board of Science and Art.

Dominion Laboratory, Wellington.

Geological Survey of New Zealand.

New Zealand Institute, Wellington.

Dominion Museum, Wellington.

EUROPE.

League of Nations, Geneva.

AUSTRIA—

Natural History Museum, Vienna.

BELGIUM—

Academie Royale, Bruxelles.

Société Royale de Botanique de Belgique, Bruxelles.

Société Royale Zoologique de Belgique, Bruxelles.

CZECHO-SLOVAKIA—
Spolecnosti Entomologické, Prague.
Plant Physiological Laboratory, Charles University, Prague.

DENMARK—
The University, Copenhagen.

FRANCE—
Société Botanique de France, Paris.
Société Geologique et Mineralogique de Bretagne, Rennes.
Société des Sciences Naturelles de l'Onest, Nantes.
Musée d'Histoire Naturelle, Paris.
L'Observatoire de Paris.
Station Zoologique de Cette (Université de Montpelier), Cette.
Société de Geographie de Rochefort.
Observations Météorologiques de Mont Blanc.
Office Scientifique des Pêches Maritimes.

GERMANY—
Naturwissenschaftlichen Verein, Bremen.
Bibliothek der B., Akademie der Wissenschaften, Munich.
Notgemeinschaft der Deutschen Wissenschaft, Berlin.
Senckenbergischen Bibliothek, Frankfurt, A.M.
Naturhistorischer Verein der preus Rheinland und Westfalens, Bonn.
Sachs Akademie der Wissenschaften, Leipzig.
Deutsche Geologische Gesellschaft, Berlin.
Zoologischen Staatsinstitut und Zoologischen Museum, Hamburg.
Gesellschaft für Erdkunde, Berlin.
Centralblatt für Bakteriologie, Parasitenkunde and Infectionskrankheiten.
Feddes Repertorium, Berlin.
Zooloogische Museum, Berlin.
Institut für Zreltwirtschaft und Seeverkehr, University of Kiel.

GREAT BRITAIN—
Cambridge Philosophical Society.
Conchological Society of Great Britain and Ireland.
Imperial Bureau of Entomology, London.
Literary and Philosophic Society, Manchester.
Royal Society of London.
Royal Botanic Gardens, Kew.
Royal Colonial Institute, London.
Royal Society of Edinburgh.
Botanic Society of Edinburgh.
Royal Irish Academy.
British Museum (Natural History).
Royal Dublin Society.

HOLLAND—
Technisthe Hoogeschool, Delft.

ITALY—
Societa Africana d'Italia, Naples.
Instituto di Bologna.
Societa Toscana di Scienze Naturali, Pisa.
Museo Civico, Genova.

POLAND—
University of Poland.
L'amon des Sociétés Savantes Polonaises.

PORTUGAL—
Academia Polytechnicada, Oporto.
Universidade de Coimbra: Instituto Botanico (Sociedade Broteriana), Coimbra.
Instituto Botanico, Coimbra.

SPAIN—
Real Academia de Ciencias de Madrid.
Real Academia de Ciencias de Barcelona.
Academia de Ciencias de Zaragoza.
Museo de Historia Natural, Valencia.

SWEDEN—
Geological Institute of Upsala University, Upsala.

SWITZERLAND—
Naturforschende Gesellschaft, Basle.
Naturforschende Gesellschaft, Zurich.
Société de Physique et d'Histoire Naturelle, Geneva.

List of Members.

CORRESPONDING MEMBERS.

David, Professor, Sir T. W. E., F.R.S. ...	The University, Sydney, N.S.W.
‡Domin, Dr. K. ...	Czech University, Prague.
‡Maitland, A. Gibb, F.G.S. ...	Geological Survey Office, Perth, W.A.
Rennie, Professor E. H. ...	The University, Adelaide, S.A.
‡Skeats, Professor E. W. ...	The University, Melbourne, Vic.

ORDINARY MEMBERS, ETC.

‡Alexander, W. B., M.A. ...	15 Edridge Road, Croydon, Surrey, England.
Allan, R. Marshall, M.D., F.R.C.S. (Edin.)	33 Bruce Street, Toorak, Melbourne.
Appleby, W. E. ...	Sugar Refinery, New Farm.
Bage, Miss F., M.Sc. ...	The Women's College, Kangaroo Point, Brisbane.
†Bagster, L. S., D.Sc. ...	The University, Brisbane.
†‡Bailey, J. F. ...	Botanic Gardens, Adelaide, S.A.
Ball, L. C., B.E. ...	Geological Survey Office, Brisbane.
†‡Bancroft, T. L., M.B. ...	Eidsvold, Queensland.
Barker, Miss E., B.A. ...	Girls' Central School, Maryborough.
Barker, G. H. ...	Adelaide street, Brisbane.
Barr, L. L. S. ...	Agricultural High School and College, Gatton.
Barton, E. C., A.M.I.C.E. ...	care of National Bank of Australasia, 4 Queen Victoria Street, London.
Beckman, G. H., B.Sc. ...	Crook Street, Northgate, Brisbane.
Berney, F. L ...	Barcarolle, *via* Longreach.
‡Bennett, F., B.Sc. ...	State School, Toowong, Brisbane.
Bick, E. W. ...	Botanic Gardens, Brisbane.
Bostock, J., M.B., B.S., D.P.M., M.R.C.S., L.R.C.P.	Wickham House, Wickham Terrace.
Broadbent, J. E. ...	Department of Justice, Brisbane.
Brown, Jas., B.A., M.D., Ch.B. (Edin.), D.Ph. (Cambridge)	"Widmoorene," Margaret Street, Toowoomba.
‡Brunnich, J. C., F.I.C. ...	Agricultural Chemist's Laboratory, William Street, Brisbane.
‡Bryan, W. H., M.C., D.Sc. ...	The University, Brisbane.
Bryan, W. W. ...	Abbotsford Road, Bowen Hills.
Brydon, Mrs. ...	Department of Public Instruction, Brisbane.
‡Buhot, E. W. ...	Department of Health, Brisbane.
Bundock, C. W., B.A. ...	"Kooralbyn," Beaudesert.
Butler-Wood, F., D.D.S. ...	Permanent Chambers, Adelaide Street, Brisbane.
Buzacott, R. H. ...	Entomological Laboratory, Meringa, *via* Cairns.
Cameron, Colonel D. C., C.M.G., D.S.O., M.P.	Parliament of the Commonwealth, Canberra.
Cameron, W. E., B.A. ...	Tattong, Victoria.
Carson-Cooling, Geo., M.Sc. ...	Boys' Grammar School, Brisbane.

† Life Members.

‡ Members who have contributed papers to the Society.

Cayzer, A., B.Sc. ... ... The University, Brisbane.
Chamberlain, W. J., M.Sc. ... ... Water Supply and Sewerage Department, Brisbane City Council
Cilento, R. W., M.D., B.S. ... ... Steamship Chambers, Eagle Street, Brisbane.
Coleman, F. F. ... ... Department of Agriculture and Stock, Brisbane.
Colvin, Joseph ... ... George Street, Brisbane.
Cottrell-Dormer, W. ... ... University, Brisbane.
Cowley, R. C. ... ... Pharmacy College, Brisbane.
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PROCEEDINGS

OF THE

ROYAL SOCIETY

OF

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FOR 1929.

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Vol. XLI., No. 1.

Proceedings of the Royal Society of Queensland.

Presidential Address.

By Professor T. Parnell, M.A.

(*Delivered before the Royal Society of Queensland, 25th March, 1929.*)

As is shown in the annual report submitted by your Council, the Royal Society, during the past year, has continued to perform successfully the function for which it was founded—"the furtherance of the natural and applied sciences, especially by means of original research"—for thirteen papers on various branches of science were read and published. The thanks of the Society are, I think, due to our two co-editors, Dr. Bryan and Mr. Longman, for the very efficient manner in which they have performed the onerous duty of seeing these publications through the press.

Another important activity entailed in this function is the bringing together of people interested in scientific work, and here, too, the Society has had a successful year, for members have had opportunities of meeting and hearing several very distinguished visitors. In this connection, also, I should like to mention the library, for, apart from our monthly meetings, it constitutes the only direct bond of union between members of the Society. Our very valuable and useful collection of books and journals is now housed in a convenient room, and tables and chairs and extra shelving have been provided with a view to making a more comfortable and convenient reference library. It is hoped that members will take advantage of the improvements and by a more general use of the library add to its value as a direct aid in the advancement of science, and as a common meeting ground for members of the Society.

Despite the expenditure on the library, the balance-sheet shows that the finances of the Society are in a satisfactory condition, and in this connection I should like, with your permission, to record our appreciation of the very efficient and untiring services of our treasurer, Mr. Bick.

It is my sad duty to record the deaths of three of our members.

Mr. William Robert Colledge died on 26th August, 1928, at the age of eighty-six. Though born in England, he spent the greater part of his life in Queensland, where he held the position of manager of the Brisbane Associated Friendly Societies' Dispensaries. His leisure time was devoted to the study of natural history and he was a recognised authority on rotifers and mosquitoes. An active supporter of the Royal Society, he held the position of President in 1910, and between 1900 and 1925 he contributed ten papers to our Proceedings. Himself an enthusiastic worker, he spared no effort in helping to interest others in natural history, and his loss will be deeply felt by this and kindred societies.

Dr. Jiri Vaclav Daněs, Professor of General Geography at the Charles University of Prague, was killed in a motor accident on 13th April at Los Angeles. In the course of his extensive travels, he visited Australia and was made an honorary member of the Royal Society of Queensland in 1910, since when he has continued to be a corresponding member. In 1919 he was appointed to a professorship at Prague, but, soon after, he left to take the post of Consul-general in Sydney, and during this second visit he continued his scientific work in Australia. He was the author of numerous publications, and by his untimely death at the age of forty-eight the world has lost one of its leading geographers.

Mr. Rowland Illidge, a past member of the Society, died on 17th February, 1929. He was born in England, but came to Brisbane at the age of nine. He was appointed a pupil teacher in 1868 but left the Department of Public Instruction in 1876, and after short service in the Railway Department he became associated with the South British Insurance Company, and later with the Commercial Union Assurance Company. He was a prominent member of the Queensland Naturalists' Club, and published many papers in the journal of that Society.

MODERN DEVELOPMENTS OF PHYSICAL SCIENCE.

As the main topic of this Presidential Address, I shall attempt to review, from certain aspects, the development of Physical Science during the past few decades, that is, during the period of transition from "classical" to "modern" physics. This period has been one of great activity in all branches of the subject, in the applied as well as in the experimental and theoretical.

The general public is inclined to over-estimate the importance of the technical side of science, to regard for instance wireless, X-rays, and motor cars as denoting the important achievements of physical science, and perhaps for this reason there is sometimes a tendency for the worker in pure science to deprecate the technical side of his subject. While essentially of secondary importance, technical science plays an important part in the development of pure science, for technical problems frequently require for their solution research work that yields results of value in pure science, and technical applications make available to the research worker instruments and appliances which make possible or greatly facilitate his experiments. More important still, the resulting demand of industry for men trained in scientific research adds very materially to the attractiveness and possibility of a scientific career, and so largely increases the number of research workers trained and interested in pure science. This fruitful co-operation between pure and applied physics and industry is growing; pure physicists are being employed in industry to an increasing extent, and members of the staffs of the research laboratories of manufacturing companies are publishing many valuable papers on pure Physics.

Of the experimental work in Physics two features call for comment: the enormous output resulting from the discovery of electrons, X-rays, radioactivity, &c., and the increase in the accuracy and in the range of experiment, due in part to the natural improvement in technique that comes with experience, and in part to the improved experimental facilities resulting from the collaboration of the physicist, engineer, chemist, and instrument maker.

For instance, the absolute measurement of resistance is a measurement of great practical importance, and has therefore been the subject of many investigations; about 1890 the probable error in the measurements was of the order of 1 in 2,000; in 1913, 2 in 100,000. Again, in 1913, X-ray wave lengths could be measured in terms of the lattice constant of rock salt with a probable error of about 1 per cent.; to-day the probable error is estimated at a few parts in 100,000.

Electro-magnetic radiation furnishes a good illustration of the extension of the range of experiment. Prior to the discovery of Hertzian waves in 1886 and X-rays in 1895, our knowledge of radiation was limited to the visible spectrum and a short distance into the infra red and the ultra violet. To-day the gaps between the Hertzian waves and the infra red on the one side, and between the ultra violet and X-rays on the other, have been filled in, and radiation is investigated over the whole range of wave lengths from more than 20.000 metres in the case of the waves used in wireless telegraphy, down to less than $\cdot 02 \times 10^{-8}$ cm. in the case of hard X-rays.

The new knowledge gained by experiment has necessitated profound modifications of physical theories, and it is these modifications, and especially the corresponding change in the outlook and the attitude of mind of physicists, that I wish to discuss.

Let us consider the position of classical physics towards the end of last century. Taking for granted the ideas of space, time, and either matter or energy, and assuming certain properties of a universal medium named the ether, it had been possible, by experiment combined with inductive and deductive reasoning, to build up what promised to be a complete description of physical phenomena. New phenomena could be described in terms of known phenomena already described in terms of the fundamental ideas; phenomena could be grouped together by scientific laws, which again could be inter-connected by physical theories; thus the dynamical theory of heat brought thermal phenomena within the realm of mechanics, and the electro-magnetic theory of light successfully connected optical and electrical phenomena. It seemed possible, therefore, that one comprehensive dynamical theory might be formulated which would embrace the whole range of physical phenomena. Certain difficulties existed, for no set of physical properties adequate to explain experimental facts could be assigned to the ether, and as a consequence it was not found possible to give a purely dynamical explanation of electrical phenomena. In this connection the following extract from a speech by Kelvin delivered during his jubilee celebrations in 1896 may be quoted:—

> "One word characterises the most strenuous of the efforts for the advancement of science that I have made, perseveringly, during fifty-five years; that word is 'failure.' I know no more of electric and magnetic force or of the relation between ether, electricity, and ponderable matter than I knew and tried to teach to my students of Natural Philosophy fifty years ago in my first session as Professor."*

That the word "failure" refers only to the final result of these particular efforts, and must not be accepted as a criticism of the value of Kelvin's work, is made clear in the following statement by the late Professor FitzGerald:—

> "Though he himself has described these efforts as resulting in 'failure' his contemporaries and disciples see a succession of brilliant successes, which have not, indeed, fully conquered the citadel of ignorance against which they were directed, but have nevertheless conquered many and fair districts, and advanced the armies of knowledge in their reconnaissance of this citadel to an extent that was only possible for a great general, an indefatigable and enthusiastic genius."†

Physics had been developed as an exact science. Starting with the fundamental assumptions, by accurate reasoning, experimental facts were co-ordinated by scientific laws which were confirmed by repeated experimental tests both direct and indirect; and these laws were co-ordinated by the accepted theories which made as few assumptions as were necessary for their effective use, and moreover these assumptions were as simple as possible, the aim being to explain the more in terms of the less complex. Mechanics appeared to be the simplest and most fundamental of the branches of physics, hence the numerous unsuccessful attempts to design mechanical models of the ether and so to formulate purely mechanical theories of light and electricity and magnetism.

This apparent exactness of classical physics we now believe to have been illusory. Ultimate truth is without meaning when considering scientific theories; the only test of a scientific theory or of a scheme of scientific description is consistency and adequacy, for, of two schemes mutually contradictory but individually consistent and adequate, it is impossible to say that one is right and the other wrong. Now certain observed facts obstinately refuse to fit into the classical scheme, which is therefore found to be inconsistent. If the building of the scheme is accurate, then the inconsistency must be due to the foundations, and critical examination has found this to be the case. Naturally, physical

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* Life of Kelvin, p. 984.

† Life of Kelvin, p. 1085.

laws have been but very slightly modified by the necessary adjustment, for these were, and are, direct statements of observed results within the accuracy of experiment, but fundamental ideas and physical theories have been profoundly altered.

Towards the end of last century the discovery of X-rays and radioactivity, and the rise of electron theory, opened up a new and wide field for research. This pioneer work naturally lacked the accuracy of the older work both in experiment and in theory. Measurements were rough, and laws and theories were formulated that only very roughly agreed with experimental results and that sometimes were mutually inconsistent. In fact, superficially, it appeared as though physics had ceased to be an exact science. This was a necessary phase of development, for rough measurements prepare the way for more exact measurements and rough theories are tentative and temporary; they suggest lines of experimental research and assist in the evolving of the more accurate theories that replace them.

One effect of this phase was, I think, a general stimulation of scientific imagination. Strict orthodoxy was no longer possible, and the minds of physicists in general were thus prepared for revolutionary attacks on fundamental principles of classical theory. The nature of these attacks and the changes which have followed are best illustrated by considering briefly the more striking developments.

In 1881, J. J. Thomson had proved theoretically that a moving charged particle possesses additional kinetic energy, and therefore additional mass, by virtue of its electric charge. The discovery of electrons and the measurement of their mass and charge gave particular importance to this conclusion, for the fact that the measured mass of the electron was very much less than that of the lightest atom suggested that the mass of the electron was entirely electrical, and as a further extension that all mass was electrical in origin. Now calculation, according to classical theory, showed that the electrical mass of a charged particle increases with its velocity, a conclusion that was subsequently proved correct by the experimental measurements of Kauffmann and Bucherer. Not only did mass, being variable, thus lose its fundamental character as a measure of matter, but it actually became indeterminate, for absolute velocity has no physical significance, only velocity relative to some fixed frame can be measured, and the Michelson-Morley experiment, which had failed to detect any motion of the earth relative to the ether, appeared to make it impossible to regard the ether as such a fixed frame of reference. Here then was a fundamental difficulty the removal of which involved modification of the foundations of classical physics, and such a solution was forthcoming. Lorentz, starting with those general equations of the electro-magnetic field which are the foundations of the electro-magnetic theory of light, considered two systems in relative motion and found that, by making certain transformations, the form of the equations became the same in either system; that is to say, an observer in *either* system would observe electrical phenomena taking place in *both* systems according to the general equations, but the observed magnitude of a particular length or time must be different for the two observers, in order to preserve this sameness of electro-magnetic equations. Thus, assuming an electron to be spherical when at rest relative to an observer, when in motion it would, as measured by him, be contracted in the direction of its velocity, and its observed electric field would differ from the field observed when at rest. In terms of his transformations Lorentz found expressions for the mass of a moving electron which are in good agreement with experimental measurements made at a later date (1909) by Bucherer.

Einstein started from a different point of view; he examined the principles of length and time measurements, and showed that the existing ideas were indefinite and inadequate; but, assuming the velocity of light in empty space to be constant, he showed that a consistent scheme resulted if existing ideas of space and time were replaced by the ideas implied in the Lorentz transformations, and thus he laid the foundation upon which he developed his theory of relativity.

The revolutionary nature of this theory is at once apparent. Mass loses its essential characteristic of constancy, and matter ceases to be a fundamental entity; time and space can no longer be regarded as having independent existence and our three-dimensional space with time as an independent variable is replaced by a four-dimensional world in which time and space are inter-related. In this four-dimensional world, as developed by Einstein and Minkowski, our ordinary perceptual ideas of physical phenomena disappear, and only the highly expert mathematician can find his way with certainty. The results of such excursions can, however, be interpreted in terms of physical phenomena and be subjected to experimental test.

Our former apparently simple concepts have, then, been replaced by more abstract and more complex concepts, but with the gain of definiteness and consistency. That the new concepts are more complex and more difficult of apprehension than the old is illustrated by the fact that many of the objections at first offered to the theory, and many of the proposed experimental tests, were based on fallacious reasoning resulting from the partial carrying over of the old ideas into the relativistic scheme.

Another feature of great significance has been the development of statistical methods of investigation and the fuller recognition of the statistical nature of many scientific laws; that is, the realisation that the regularity of the phenomena described, and therefore the accuracy of the laws, depends on the fact that the observed phenomena represent the average effects of an enormous number of events occurring in an irregular haphazard fashion. This development is a necessary outcome of atomic theories. Towards the end of last century, the atomic theory of the structure of matter and the dependent molecular and kinetic theories were indispensable to physicists and chemists, but it was impossible to observe directly the properties of an individual atom or molecule, so that "molecular reality" was still an open question. Since then the investigation of electrons and gaseous ions has led to the theories of the atomicity of electricity and the electrical structure of the atom; moreover, owing to the great amount of energy possessed by certain ions it has been possible to observe the behaviour of individual particles, and thus the atomicity of matter and of electricity has been brought from the realm of speculation into the range of experimental knowledge.

Most of our experimental observations, however, are large-scale observations concerned with very large numbers of atoms and so involving very large numbers of discrete phenomena; they therefore deal with average effects only, and do not give us direct and unequivocal information as to the nature of the individual phenomena. The observed pressure and temperature of a gas are such average values representing the average effects of the motion of individual molecules, and the kinetic theory is a statistical investigation of the phenomena; making as few and as simple assumptions as possible as to the nature of the molecules and their encounters, it explains the properties of gases, but it does not give us an exact account of the dynamics of an individual encounter. An essential feature of such statistical investigation is the use of the laws of probability. It would be quite impossible, for instance, however simple our dynamical assumption, to investigate mathematically the history of any one molecule, but, by assuming that a number of occurrences are equally likely, we are able to calculate the most probable average properties of ordinary molar quantities of gas which contain very large numbers of molecules.*

As far back as 1877, Boltzmann had given an explanation of entropy in terms of probability and thus arrived at a statistical proof of the second law of thermodynamics, but the fuller development of this idea did not occur till the beginning of this century. The second law of thermodynamics deals with the transfer of heat; it states generally that the spontaneous transfer of heat is from hotter to colder bodies, and so asserts a general tendency towards equalisation of temperature. It is a law that is very readily applied to physical and chemical problems, and forms the basis of a vast amount of theoretical work, the conclusions of which are in agreement with experiment, so that it is regarded as a very general physical law of tested validity within its sphere of operation. If we extend its sphere of operation to include the whole universe, we arrive at the conclusion that a universal and continuous degradation of energy is taking place, and that the universe as a whole is moving towards a state of stagnation in which no further energy transfers are possible.

As a statistical law, however, based on probability, the second law of thermodynamics states the most probable results. Dynamically a slower moving molecule may give up energy to a faster molecule, and, from the point of view of dynamics, there is no reason why, in a vessel containing a gas, the faster moving molecules should not drift to one

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* 1 c.c. of gas under normal conditions of temperature and pressure contains 27 x 10^{18} molecules.

side and the slower to the other, thus causing a measurable difference of temperature in the gas; just as there is no reason why a bridge player should not receive a hand consisting of thirteen spades every deal for ten years. In each case, however, probability calculations show that the odds against such an occurrence are so enormous as to make it unnecessary for us to take the possibility into practical consideration.

While, then, we can use the second law of thermodynamics with every confidence in the sphere of action proper to it, we cannot assume it to be of universal validity, we can only use it in relation to phenomena such that the laws of probability may be assumed to be valid.

Similarly, the atomicity of electricity indicates that our experimental laws in electricity and magnetism are statistical laws and that our practical measurements represent average values. Ohm's law, for instance, states the *large scale* experimental fact that, to a very high degree of accuracy, the current in a conductor is proportional to the electric force; on the *small scale*, the current consists of a drift of electrons and the electric force varies very rapidly from point to point inside the conductor, which itself becomes a structure of electric charges. Current and electric force therefore are measured only as average values, and though the statistical law is so simple no satisfactory theory has yet been advanced which describes the actual movements of individual electrons within the metal. An electric current, then, can no more have a constant value than can the number of sheep passing per second through a wide gate; the current may have a constant *average* value but fluctuations must exist, and, in some cases, it is possible to detect them experimentally. In a wireless valve, the electrons are emitted from the hot filament in haphazard fashion, and, for a steady average value of the anode current, fluctuations will be present whose nature and magnitude can be calculated in terms of probability. By means of a special amplifier, Hull measured these fluctuations and obtained results in good agreement with theory.

The first step in modern electrical theory is to ascribe to the electron and the proton, which are the "atoms" of electricity, the simplest properties which will account for our large-scale electrical laws. Now the basic laws of electricity and magnetism can only be accurately expressed in terms of mathematical analysis. For instance in calculating the force between two charged bodies by means of the inverse square law, it is necessary to consider the actual charges as built up of a large number of elements of charge. The obvious procedure, therefore, is to ascribe to electrons and protons the properties of such elements of charge, and so to assume that they will behave in accordance with the general laws of electro-magnetism. The validity of this assumption will be discussed shortly.

The behaviour of electrons and of charged atoms and molecules has also been studied by more direct methods; the deflections of such particles in electric and magnetic fields have been measured and the results of such experiments are consistent with the above assumption, provided that the necessary relativity corrections are applied in the case of the faster moving particles. Again, during certain radioactive changes, charged helium atoms known as α particles are ejected with such high velocity that a single one impinging on a fluorescent screen produces a visible flash of light, or passing into a suitably arranged ionization chamber gives rise to a detectable amount of ionization, and thus direct observation of individual particles is possible. Observation shows that these particles are emitted in haphazard fashion, and that regularity only appears when average values are considered. This suggests that any one atom is just as likely to disintegrate as any other—that is, that the disintegration of the atoms is a chance occurrence, and that therefore the probable number disintegrating in any short interval of time will be a definite fraction of the whole number, from which the exponential law of decay is an immediate deduction. The experimental validity of the exponential law of decay thus confirms the result of direct observations; the regularity of the statistical law of decay confirms the assumption of irregularity or fortuitousness of the individual disintegrations.

The work of Rutherford and others on the scattering of α particles by matter also gives a good illustration of the direct use of statistical methods. A narrow beam of α particles was allowed to impinge on a thin sheet of metal foil, and the relation between the angle of deflection and the proportion of the whole number deflected to this extent was determined by direct counting. Assuming the inverse square law to hold for the force between an α particle and the nucleus or positive portion of an atom their shortest distance apart was calculated in terms of the angle of deflection, and by probability calculations, a formula was deduced giving the average distribution of the scattered particles. The agreement of observed results with the formula for a given range of angles of deflection was evidence, therefore, of the validity of the inverse square law for a corresponding range of distances. In this way it was possible to prove indirectly that the inverse square law holds at distances very small compared with the size of the atom, and therefore that the nucleus itself is very small—results of the greatest importance in theories of atomic structure.

This brief discussion of statistical laws is sufficient, I think, to indicate certain general points of view.

Statistical laws, though of the greatest practical importance, from their very nature cannot be regarded as exact in the mathematical sense. It is common to hear physics described as an exact science and biology as inexact; the difference is one of degree, and the greater accuracy of physics is in part due to the fact that atoms and electrons are smaller and more numerous than the units of the biologist. Many methods of attack are common to both and we may expect in the future, at any rate in statistical science, even more mutual inspiration between workers in the two subjects.

Again, statistical laws, being based on probability, can only be expected to hold good when probability calculations are possible, that is, for phenomena such that we may assume we are dealing with groups of large numbers of events all of which are equally probable. Any fresh influence therefore introduced into such a system may upset this equality and invalidate our conclusions. If, for instance, a homogeneous steel cube be tossed into the air and allowed to fall to the ground, we can state as a statistical law that for any large number of trials, N, a given face will be uppermost approximately $N/6$ times, and the larger N the greater the accuracy of the law. If, however, the cube were magnetised, the symmetry would be destroyed and this statistical law would no longer be valid. Until, then, it is definitely demonstrated that life and mind cannot be regarded as possibly constituting such influences, the physicist cannot assert that statistical physical laws will necessarily apply to biological phenomena.

Again, statistical laws are unsatisfying from the philosophical point of view; they give us the practical effects of a number of discrete events, but do not describe the individual events themselves. Working back from statistical laws we can find descriptions of the elemental events which are satisfactory as far as these laws are concerned, but we cannot assert that these descriptions are correct, for others might be equally satisfactory. We can, however, assert that a description is incorrect or incomplete if we find that in some new connection it leads to conclusions inconsistent with experience. As mentioned above, the assumption that individual electrons and protons behave in accordance with the general equations of the electro-magnetic field is consistent with the more basic experimental laws of electricity and magnetism and with such direct measurements on electrons and ions as have been possible, but the phenomena here involved are large-scale phenomena and we are not justified in expecting that the same description will necessarily be satisfactory for the atomic scale, and, in fact, all attempts to apply classical electro-magnetic theory to electrons within the atom have resulted in failure.

The problem of atomic structure affords a good illustration of this difficulty: A static atom built up of protons and electrons and having the nuclear structure demonstrated by Rutherford's experiments cannot be stable, while a dynamic atom consisting of electrons describing orbits about the nucleus as do planets round the sun is also impossible according to classical theory, for the electrons, having acceleration, would radiate energy and the orbits would therefore contract until the electrons fell into the nucleus; moreover, such an atom could not emit radiation corresponding to the sharp lines found in spectra.

A partial solution of the problem came from the development of quantum theory. About the beginning of this century Planck began his theoretical investigations of the radiation from hot bodies. He found that calculations based on classical theory gave results inconsistent with experiment, and was thus led to postulate a kind of atomicity of radiant energy. The basic assumption of the quantum theory is that radiant energy is emitted and absorbed not continuously but in definite discrete "atoms" known as quanta, but unlike the "atoms" of electricity these quanta of radiant energy are not all equal, for the amount of energy in a quantum is equal to the frequency of the radiation multiplied by a universal constant known as Planck's quantum of action. This theory soon found other applications to hitherto unsolved problems such as the phenomena of photo-electric emission and the variation of the specific heats of solids with temperature, but its most fruitful development commenced in 1913 when Bohr published a quantum theory of the structure of the hydrogen atom which accurately explained the observed relation between the frequencies of certain series of lines in the hydrogen spectrum.

Bohr's model of the hydrogen atom incorporated Rutherford's positive nucleus and consisted of a proton as nucleus with a single electron describing an orbit about it in accordance with the inverse square law of force; the path of the electron is therefore a circle or an ellipse, but at first Bohr only considered circular orbits. According to classical theory, any ellipse would be a possible orbit, its size depending on the total energy of the atom, and again in any orbit the electron would be radiating energy, but Bohr based his theory on three postulates which represent radical departures from classical theory. Planck's universal constant h has the dimensions of energy multiplied by time, that is, the dimensions of "action," which is a most important quantity in generalised mechanics. Bohr assumed—

(i.) that only those orbits are possible for which the "action" is a whole number multiple of h (for circular orbits this means that the angular momentum is $nh/2\pi$);

(ii.) that these orbits are non-radiating;

(iii.) that radiation occurs when the electron passes from one orbit to another, and that the frequency of the radiation is given by $\nu h = E$, where E is the decrease in energy of the atom.

This theory has since been extended to include elliptic orbits and atoms with more than one extra-nuclear electron, and has proved of the greatest value in introducing regularity and order into spectroscopy. In the spectrum of any element it is possible to select sets or series of lines whose frequencies show a simple arithmetical relation, and such spectral series occur in the infra red, the visible, the ultra violet, and in X-ray regions. Quantum theory not only explains such series, but also explains the effect on lines of electric and magnetic fields, and again the fact that certain series of lines are multiple.

Two of the simpler applications will serve to illustrate the accuracy of the theory and also the accuracy of modern spectroscopy. An atom of helium that has lost one electron should have the same structure as an atom of hydrogen, and should therefore give similar spectral series. This is found to be the case, but accurate measurements show that a constant known as the Rydberg constant, which appears in the mathematical formula describing the series, is slightly different for the two, being 109677·70 ± ·04 for hydrogen and 109722·14 ± ·04 for helium. The difference between the two values arises from the motion of the nucleus, for the electron describes its orbit, not about the centre of the nucleus, but about the centre of mass of the two; from these two values, then, the ratio of the mass of the electron to the mass of the hydrogen atom can be calculated, and the result is found to agree with other determinations of this ratio within the limits of experimental accuracy. Again, in the case of the hydrogen atom or the singly ionized helium atom, if the mass of the electron is supposed constant, all elliptic orbits with the same major axis should correspond to the same amount of energy; but, if the variation of mass with velocity demanded by the theory of relativity is taken into account, the energy depends to a slight extent on the shape of the orbit as well as on its major axis. By making the relativity correction and applying quantum principles to the shape as well as the size of the orbits, Sommerfeld showed that the lines of certain series in the spectra of hydrogen and of ionized helium should have a "fine structure," each apparently single line really consisting of several lines very close together. This fine structure has been observed, and measured values of the separation of the lines are in satisfactory agreement with the calculated values.

For a final illustration of the possible scope of quantum theory and also of the unfettered flights of modern physical theories, we may pass from the ultra-microscopic world of the atom to the world of stars and interstellar space. According to the theory of relativity, when a body gains or loses energy its mass increases or decreases by an amount equal to the energy change divided by the square of the velocity of light, and thus mass and energy appear to be mutually convertible—a view that is supported by astronomical measurements of the size and brightness of the fixed stars.

Now for the past thirty years various investigators have measured the electrical conductivity of gases that remains after all obvious causes have been allowed for, and experiments at different altitudes and under very various conditions of immediate surroundings suggest that this residual conductivity is due to radiations reaching the earth from outside. Measurement shows that such radiation must be much more penetrating and therefore of much higher frequency than any known radiation of terrestrial origin, for a screen of 70 cm. of lead only reduces its effects to about one-half. Some observers claim that they have detected a greater intensity from the direction of the Milky Way, but there is no decisive evidence that the intensity varies with the direction; the conclusion is therefore that there exists a cosmic radiation originating in interstellar space of frequency much higher than that of the hardest γ rays.

Millikan and his colleagues, by sinking electroscopes to different depths in a snow-water mountain lake, measured the absorption of cosmic rays by water, and have analysed the results with a view to determining the frequencies present. Millikan concludes that the cosmic ray spectrum consists of certain definite frequency bands, and in a recent paper he shows that these frequencies are consistent, in terms of relativity and quantum theory, with the view that cosmic radiation is due to a process of atom building taking place in interstellar space. He identifies three calculated frequencies with the formation from protons and electrons of helium, oxygen and silicon atoms, and finds that the relative intensities of cosmic rays of these frequencies correspond with the relative prevalence of these elements in meteorites.

The total annihilation of an atom of hydrogen by the proton and electron neutralising each other would give radiation of a frequency about four times as great as that of the hardest rays observed; Millikan concludes, therefore, that cosmic rays give no evidence of the disappearance of matter in interstellar space, and that this process is restricted to the interior of stars.

Thus, from observation of the rate of discharge of an electroscope under different conditions, it has been possible to build up a quantitative theory of atom building in interstellar space. Interpreting observed facts in terms of modern theory, it is possible, then, to formulate the following theory of cosmic processes:—Protons and electrons, which exist in abundance in interstellar space, there combine to form atoms, and in so doing emit cosmic rays; these atoms aggregate under gravitation forming stars in the interior of which, under conditions of very high temperature and pressure, matter is converted into energy which eventually passes to the outside of the star and is radiated. To complete the cycle, Millikan adds the suggestion, as yet unsupported by experimental fact, that in interstellar space radiation may be reconverted into protons and electrons. On the other hand, Jeans, who also has devoted much attention to cosmic physics, regards the second law of thermodynamics as universally valid, and so rules out the possibility of Millikan's last assumption.

Great as have been the achievements of quantum theory, it is impossible to regard it as yet adequate or mentally satisfying. It describes accurately the emission and absorption of radiation, but fails to describe transmission phenomena such as interference and diffraction. The rules for applying quantum theory to atomic structure at first sight seem mystic rather than scientific; the theory gives no account of the actual process of radiation, but merely represents it as the result of the passage, in some uncomprehended fashion, of an electron from one orbit to another, and there is the philosophic difficulty that the nature of the radiation depends only on the initial and final orbits, with the implication that the present functioning of the electron is decided by its future state.

Notwithstanding these difficulties and inadequacies, applications of quantum theory have been so successful that it seems certain that the theory, while not the whole truth, is at least partially true; the quantum of action appears to be indispensable in physical theory and there is little doubt that it will be embodied in future theories which, for instance, will describe the process of radiation emission and adequately explain optical phenomena as statistical large-scale manifestations of discrete small-scale processes.

Numerous attempts have been made to devise schemes of quantum mechanics which give correct results when applied to atomic processes and yet avoid the difficulties of the ordinary quantum theory. Perhaps the most successful of these is wave mechanics, which is based on the analogy between wave motion and the motion of particles. In classical mechanics it can be shown that, for a particle moving in a field of force, the path of the particle between any two points is such that the "action" is a minimum, and similarly in geometrical optics the path of a ray of light is such that the time taken is a minimum. With a suitable choice of symbols and conditions it is possible, therefore, to make a set of equations represent either rays of light or the motion of particles.

In accordance with the wave theory of light, rays of light must be replaced by wave motions, and the principles of geometrical optics can only be applied when we are considering large distances. For distances comparable with the wave length of light, quite different principles apply, as is shown by the phenomena of diffraction. Following this analogy, if the motion of a particle is represented by the equation of a wave motion, classical mechanics becomes a large-scale description corresponding to geometrical optics, but, for atomic distances, the principles of classical mechanics no longer hold and the principles of wave motion must be substituted. In wave mechanics then, an atom is represented by a set of wave motion equations, and from these mathematical equations the facts of spectroscopy can be deduced.

This brief account, inadequate as it is, may serve to indicate the profound changes that have occurred in the world of physical theory. The perceptual materialistic world of classical theory has been replaced by a world of mathematical abstractions and at times we appear to have lost touch with "reality"; space and time have no separate existence and matter has been reduced to sets of mathematical equations or, if preferred, to systems of wave motions.

But, after all, what is meant by reality in physical science? Questions concerning objective reality are outside the scope of experimental science, for it is impossible to state that any particular concept, matter for instance, has a real existence; it can only be stated that certain concepts are consistent with our description of observed facts, so that, in the only sense in which the word has any meaning in physical science, reality is subjective and relative. A concept which is immediately necessary for our description of experimental facts, and with which we are familiar through constant use, we regard as representing something "real," and in the same way we regard a theoretical explanation as mentally satisfying if it is given in terms of concepts of a type that we recognise as familiar.

Kelvin objected to Maxwell's electro-magnetic theory of light as an attempt to explain *ignotum per ignotius.* To him, the electrical explanation was unsatisfying and only a consistent mechanical explanation would have been acceptable, but I think that, to a modern wireless engineer, alternating electric and magnetic forces in an electro-magnetic wave are as "real" as pressure variations of the air in a sound wave.

Our ideas necessarily become more seemingly abstract as our knowledge increases. The definitions of electric force and magnetic force given in elementary text-books appear to be quite reasonably simple and practical, but, with increasing knowledge and as our ideas become more exact, we find that the "practical" aspect of the definitions is refined away till finally we come to the conclusion that the only accurate definitions of these quantities are given by the general equations of the electro-magnetic field.

New ideas are never appreciated at once, for it takes time for them to become familiar and therefore "real" to us. For instance, the ideas of relativity are now far more acceptable to everyday physicists than they were fifteen years ago, and, unless the theory of relativity has been replaced by some more satisfactory theory, in fifty years' time the four-dimensional world of relativity will seem as "real" to everyday physicists as three-dimensional space seemed to us a few years ago.

Absolute truth has no more meaning in physical science than has objective reality. We may draw comfort from an instinctive feeling that absolute truth exists as an elusive goal towards which we are slowly finding our way, but we can never hope to state a law or theory as absolute truth. In physical science the word "truth" can only be used to imply consistency, and the aim can only be towards a more comprehensive and accurately consistent description of phenomena. The scheme of Newtonian mechanics has been found to be inconsistent with observed facts, and examination has traced these inconsistencies to faulty fundamental assumptions. This scheme has been replaced by the relativistic scheme, which does not lead to these inconsistencies and is therefore regarded for the time being as "true"; but the theory of relativity also makes fundamental assumptions, and should inconsistencies be discovered or a more satisfactory theory be devised, it will become "untrue" and be replaced.

In the development of satisfactory theories, partially true theories play a valuable part, for, to a limited degree of accuracy or within a limited range of phenomena, they systematise facts, and used deductively they suggest new methods of experimental attack; moreover, by selecting and combining ideas from several such partial and tentative theories it may be possible to develop a more comprehensively consistent and therefore more acceptable theory. The increased specialisation of scientific workers tends towards the use of such partially true theories. For instance, the Rutherford-Bohr atomic model has proved of the greatest value in spectroscopy, but that it is a very complicated model is obvious if we try to visualise, say, the atom of gold with its seventy-nine electrons describing approximately elliptic orbits about the central nucleus. It cannot readily be used to explain the arrangement of atoms in molecules or to explain the molar physical and chemical properties of matter. On the other hand, the Lewis Langmuir type of static or *quasi* static atom model cannot be reconciled with any reasonable scheme of dynamics, and cannot satisfactorily explain radiation phenomena, but can explain the properties of the elements and so finds readier application in chemistry. There are then two groups of scientific workers using two distinct and contradictory models of atomic structure, but the members of each group know that both models are unsatisfactory and will sooner or later be replaced by a more satisfactory model which will include the good points of both.

At the present time any theory, however speculative, receives attention if it has scientific value, that is, if it can be usefully applied to physical phenomena and be subjected directly or indirectly to the test of experiment.

The comparative orthodoxy of classical physics has given way to a healthy agnosticism characterised by greater tolerance and freedom of thought, increased scientific imagination, and a better realisation of the evolutionary nature of scientific concepts and theories.

The loss of the illusion of definiteness and reality has resulted in a wider and clearer vision, and, whether their period of usefulness prove short or long, the new ideas of relativity and quantum theory which have emerged from the confusion attending the partial collapse of classical theory mark a great advance in physical theory, an advance that profoundly influences all scientific and philosophic thought.

The Volatile Oil of Queensland Sandalwood (*Santalum lanceolatum*).

By T. G. H. Jones, D.Sc., A.A.C.I., and F. B. Smith, B.Sc., F.I.C.

(*Tabled at the Royal Society of Queensland, 25th March, 1929.*)

Santalum lanceolatum is one of the most notable representatives in the Queensland flora of the family Santalaceæ, and it has for some years afforded a faintly perfumed wood which has constituted an article of export to Chinese markets, where it is stated to find use in the manufacture of joss-sticks and small fancy wooden articles.[1] So far as is known to the authors the wood of this Queensland-grown sandalwood has not hitherto been distilled for essential oil, but Guildmeister and Hoffmann[2] record constants of a sandalwood oil from Thursday Island which probably would have been derived from this species. A. R. Penfold in a recent paper, "The Chemistry of Western Australian Sandalwood Oil,"[3] describes an investigation commenced in 1925 of commercial and laboratory-distilled oils including oils derived from *S. lanceolatum* of Western Australian origin, in which state the wood is distilled and the oil admixed with oil from *Eucarya spicata* (*Fusanus spicatus*) to constitute commercial Western Australian sandalwood oil.

The authors' examination (commenced in 1924) of oils derived from Queensland woods has been practically contemporaneous with that of Penfold, and their results are considered sufficiently complete to warrant publication, particularly as they show a more considerable and variable range of optical rotation than recorded by that author, the high negative character of whose figures, we believe, may have been fortuitous. The oils described were, in the absence of efficient apparatus for conduct of steam distillation of the wood in bulk, derived by percolation of the wood shavings three times with low-boiling petroleum ether and distillation with glycerine *in vacuo* of the volatile oil from the extract, an adaptation of the method of Briggs[4] for estimation of essential oil in sandalwood.

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[1] We are informed by Mr. C. T. White (Government Botanist) that though the tree has a wide distribution through North-western Australia, the Northern Territory, Queensland, and New South Wales it is only those trees growing in the more tropical portions that possess a wood with a typical sandalwood odour, the wood of trees growing in Southern Queensland and New South Wales being entirely or almost entirely scentless. The wood of the Southern trees has in consequence no commercial value.

[2] Guildmeister and Hoffmann, "The Essential Oils," vol. ii., p. 347.

[3] Journal Proc. Roy. Soc., N.S.W., vol. lxii., 1928, 60–71

[4] Jour. Ind. Eng. Chem. 1916, 420.

The oils so obtained to the extent of about 4 per cent. on the large scale[5] were clear, somewhat viscous, and bright yellow in colour. The odour in the cold was faint but was strongly aromatic on heating. In its comparative inodorousness in the cold it is thus contrasted with the oil of East Indian sandalwood (*Santalum album*) and the distinctly aromatic commercial West Australian oil derived principally from *Eucarya spicata.* The odour of the West Australian oil, which indeed closely resembles that of East Indian oil, is to be ascribed no doubt to the presence of santalol, which Penfold considers from application of the santalenic acid test to be present to the extent of 40 to 45 per cent.

On the other hand oxidation of the oil of *Santalum lanceolatum* with potassium permanganate in the manner prescribed by Chapman and Penfold (*loc. cit.*) failed, in the hands of the authors, to yield a substance identifiable with santalenic acid, and for this reason it is believed that santalol is not a constituent of the volatile oil of *Santalum lanceolatum.*

It will be observed, from consideration of the constants given in Table I., that there is considerable variation in the constants of the oils derived from trees in various parts of Queensland. Although in the main the oil derived from coastal districts (such as that of the bulk of our wood which came from Cooktown) resembles that of the West Australian *Santalum lanceolatum* oil in the high negative optical rotation, nevertheless oil derived from trees at Hughenden and Atherton shows a much smaller negative rotation.

In the case of a small sample (6 lb.)[6] obtained from Hughenden in 1928 a positive rotation was recorded for the oil, but larger supplies forthcoming at a later date[7] from this same area failed to reproduce the positive rotation, and we were thus unable to complete the examination of this unique variety of oil with its positive rotation. The variation in optical rotation, accompanied by less noticeable variations in density, is no doubt due to variation in the proportions and rotations of the optically active alcohols and terpenes which are the constituents of the oils.

As most of our oil was from wood received from Cooktown and possessed of high negative rotation, our investigation has chiefly centred around this oil and the main results are to be ascribed to it.

The principal constituents of all the oils are alcohols which form 80 to 90 per cent., together with smaller quantities of sesquiterpene. The alcohol consists of a mixture of two and possibly three isomeric sesquiterpene alcohols, the principal one possessing a specific rotation of approximately —63. That this is also the principal constituent of oil

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[5] Small-scale ether extractions gave a yield of 5 per cent.: this oil slowly deposited a small amount of crystalline material.

[6] Sample 5.

[7] Sample 6. The density of the alcohols from this sample was, however, higher than from the others except sample 5.

of West Australian origin is indicated by Penfold's description of a fraction therefrom with specific rotation —70·4 and our own examination of a sample of this oil obtained by courtesy of the Forestry Department, West Australia.

A second alcohol was obtained with notably high density (·9908) and positive specific rotation (+28), and there also appeared to be further indication of a third alcoholic constituent with somewhat higher density than the main alcohol previously noted.

It is doubtful if these alcohols were obtained in a state of high purity on account of the difficulty of separating them completely by fractional distillation *in vacuo;* the third-mentioned was apparently present only in small amount, and its even partial separation appeared to be inhibited by gradual resinification of the higher fractions. Penfold separated a similar dextro-rotatory alcohol to the above from the oil of *Eucarya spicata* by differential combination with phthalic anhydride. We were, however, unable to effect any clean separation of the dextro- and lævo-rotatory alcohols of *Santalum lanceolatum* by this method, although a rough separation is undoubtedly obtained. The authors consider that the constants recorded for the lævo-rotatory alcohol by Penfold were no doubt derived from a purer sample than they were able to obtain even after prolonged fractional distillation, due in all probability to the almost complete absence of the dextro-rotatory alcohol in the sample examined by him; and our examinations of oils from different localities in Queensland seems to indicate that the percentage of this dextro-rotatory constituent is variable, falling to a minimum in highly negative oils.

EXPERIMENTAL.

TABLE I.

Constants of Sandalwood Oils (Santalum lanceolatum).

Locality.	Density $d_{15\cdot5}$	Specific rotation $[\alpha]$ D	Refractive Index n_D^{20}	Acetyl Value.	% of Alcohols present.
1. Cooktown 1926 ..	·9554	− 47·1	1·5062	191·9	88
2. Cooktown 1927 ..	·9522	− 42	1·5068	186	86
3. Hughenden 1927 ..	·9592	− 8	1·5062	187	86
4. Atherton 1927 ..	·9612	− 17	1·5068	180	82
5. Hughenden 1928 ..	·9756	+ 12	1·5100	184	85
6. Hughenden 1928 ..	·9533	− 30	1·5050	186	86
7. West Australia (supplied by Forestry Department)	·9607	− 42·6	1·5004	161	73
8. West Australia (distilled by Penfold)	·9446	− 61	1·5055	193·4	89
9. Atherton 1925 ..	·9546	− 30	1·5050	184	85

Sample 9 was obtained by steam distillation of shavings, and the oil was found to differ very little from the other petrol-extracted oils.

Fractional distillation of Sandalwood oil.

Five hundred cubic centimetres of oil $[a]$ D —47·1 were fractionally distilled at 5 mm. pressure. The data of fractions obtained in one such distillation are recorded in Table II.

TABLE II.

Fraction.	Boiling Point.	$d_{15\cdot5}$	$[a]$ D	n^{20}_{D}
20 cc.	0–124°C.	·9106	− 33	1·4930
36 cc.	124–138°C.	·9395	− 38	1·5002
146 cc.	138–141°C.	·9522	− 45	1·5038
148 cc.	141–146°C.	·9530	− 53	1·5054
150 cc.	146–152°C.	·9540	− 58	1·5055

Separation of alcohols by treatment with phthalic anhydride.

For separation of the alcohols recourse was had to the standard phthalation process. In a typical experiment 100 grammes of oil were heated with an equal bulk of phthalic anhydride and 75 cc. benzene under reflux. The bulk of the phthalation was effected in one hour but was continued for two hours. Alcohols still uncombined with phthalic anhydride were subsequently further treated at 140 deg. C. in the absence of benzene. The total acid phthalates were decomposed by hydrolysis with alcoholic sodium hydroxide, and the recovered alcohols distilled completely for purposes of clarification. The constants of the alcohols recovered from various samples of oil are recorded in Table III.

TABLE III.

ALCOHOLS SEPARATED FROM SANDALWOOD OILS.

Sample.	$d_{15\cdot5}$	$[a]$ D	n^{20}_{D}
1	·9549	− 51·5	1·5060
2	·9566	− 44	1·5082
3	·9600	− 9	1·5100
4	·9663	− 19	1·5104
5	·9884	+ 17	1·5110
6	·9698	− 35	1·5104
7	·9587	− 47	1·5010
8	·9474	− 70·4[8]	1·5074
9	·9578	− 33·4	1·5010

[8] The figures quoted for sample 8 were derived from Penfold's paper (*loc. cit.*).

The alcohols from sample 5 were unique in possessing a positive rotation and unusually high density, but only a small sample of this oil was available. It was not possible to examine it closely, but it would seem that the alcohol of positive rotation reached a much higher proportion in this oil than in the others, and indeed became the dominant constituent.

Fractional distillation of the alcohols.

In order to separate the alcohols from one another, prolonged fractionation under 5 mm. pressure was resorted to. The figures quoted in Table IV. refer to the fractions obtained in the first fractionation of the alcohols (1,200 cc.) obtained from sample 2.

TABLE IV.

—	Fraction.	$d_{15\cdot5}$	$[a]_D$	n_D^{20}	B.P. Range.
1	235 cc.	·9593	− 36	1·5086	140°C.
2	250 cc.	·9544	− 41	1·5084	
3	260 cc.	·9536	− 45	1·5080	to
4	250 cc.	·9522	− 50	1·5080	
5	145 cc.	·9560	− 55	1·5076	150°C.

It will be seen from this table that the presence of three alcohols is indicated, but on further fractionation it was found that one of these was present to a much greater extent than the others.

Ultimately after prolonged fractionation two alcohols were separated in a state of approximate purity, for which the following constants were recorded:—

Alcohol No. 1.

$d_{15\cdot5}$ ·9908 $[a]_D + 28$ n_D^{20} 1·5127 b.p. 142°C. 5 mm. pressure.

Molecular Composition—$C_{15}H_{24}O$.

The percentage of this alcohol in the mixed alcohols could scarcely exceed 10 per cent. and was probably less than this.

Alcohol No. 2.

$d_{15\cdot5}$ ·9510 $[a]_D - 63$ n_D^{20} 1·5062 b.p. 148°C. 5 mm.

Molecular Composition—$C_{15}H_{24}O$.

This alcohol—possibly a mixture of closely similar isomers—is the dominant constituent of the oil and constitutes at least 80 per cent. of the mixed alcohols, being responsible for the usual pronounced lævo-rotation of the oils.

The constants quoted by Penfold for this alcohol are—

$d_{15\cdot5}$ ·9474 $[a]_D - 70{\cdot}4$ b.p. 163°–165° 5 mm.

which resemble those given above in all except the boiling point which is 15 deg. C. higher. We were unable to confirm this high boiling point.

Sesquiterpene constituents of oil.

Repeated fractionation of the original oils led to the isolation of a fraction with a somewhat lower boiling point than the alcohols. As preliminary examination indicated the presence of sesquiterpene, the fraction was repeatedly distilled over metallic sodium and finally collected as a colourless liquid with the following constants:—

$d_{15\cdot5}$ ·8954
$[\alpha]_D$ —30
n_D^{20} 1·4960
Molecular composition $C_{15}H_{24}$

The sesquiterpene did not give the usual colour reaction with bromine vapour and acetic acid.

The investigation of the constitution of this sesquiterpene and the alcohols described is being continued.

The authors wish to express their thanks to the Forestry Board, Queensland, for their usual courteous assistance in obtaining samples of sandalwood from their various forest stations; to Mr. C. T. White, Government Botanist, for verification of authenticity of specimens; and to the Chemical Society Research Fund for a grant to one of us (T.G.H.J.) which defrayed part of the cost of this investigation.

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The Relative Value of Larval Destructors and the Part they play in Mosquito Control in Queensland.*

By Ronald Hamlyn-Harris, D.Sc.

(*Read before the Royal Society of Queensland, 27th May, 1929.*)

The idea of controlling mosquitoes by means of their natural enemies sounds so exceedingly attractive that many are tempted to place an unwarranted amount of confidence in what has rarely proved of any great value. That natural enemies, under natural conditions, are capable of taking a large toll of mosquito life cannot be denied, and for that reason alone they are worthy of considerable encouragement. In a country like ours, subjected to severe drought conditions, waters change so rapidly, topographically as well as in physical and chemical characteristics, that it would be very unwise to place false faith in what we know only to be effective under the most ideal of conditions. Nature erects many natural barriers against the undue preponderance of most larval destructors and against fish in particular. Yet the question of biological control is vastly important, and it is necessary that we should have a thorough knowledge of those natural enemies which we believe to exist and which might be of some value on the one hand in order to apportion them as opportunity affords, and on the other to prevent their ruthless destruction due to ignorance.

The presence of numerous mosquitoes in any given water may be taken as evidence: (1) That the water is in itself suitable for their development; (2) That the food which that particular type of mosquito larva requires is available.

On the other hand the absence of mosquito larvæ in certain waters may be due to a great variety of causes as yet but very imperfectly understood. The absence of suitable food is possibly the most important, and by far the most far-reaching, factor influencing selection.

Where there is a total absence of food due to the presence of larger aquatic animals, mosquito larvæ do not occur. Sometimes there is an abundance of organic matter, together with certain poisonous excretory material, which is responsible for a low oxygen content of the water; and these factors, amongst others, doubtless have a direct bearing upon the attractiveness or repulsiveness of the water in question, sometimes to such an extent that the smaller varieties of larval destructors become scarce whilst fish would probably, under such circumstances, not live at all. Unless suitable conditions exist for larval destructors to maintain themselves, there can be no control of mosquitoes along these lines.

* From the Entomological Section of the Department of Health, Brisbane City Council.

TYPES OF WATERS.

The types of waters selected by mosquitoes require detailed study. In earlier campaigns it was a common practice to oil, to drain, or to fill every potential breeding place irrespective of whether it was breeding mosquitoes or not, and very little attention was given to the type of water concerned. This rather drastic method proved fruitful of good results, but it is recognised to have been an exceedingly expensive method of control, for it is now considered quite unnecessary to interfere with waters which are not in any way a mosquito menace. Modern methods demand that the examination of the water be made in detail, and that its whole natural surroundings and contents be taken into consideration in order to ascertain the factors involved in rendering such waters attractive or unpalatable as the case may be. Such anti-mosquito work involves considerable entomological study, specially with regard to the bionomics of each different type of mosquito encountered. It is extremely difficult to make this phase of the question clear to the lay mind, but as so very frequently the layman has to find the necessary sinews of war it is highly desirable that the problem from this standpoint should be understood by him.

THE CHARACEÆ AS POSSIBLE LARVICIDES.

It has been thought by some that the presence of certain Characeæ in natural waterholes is sufficient to prevent mosquito breeding in waters in which they occur, but our experience here in Brisbane totally disproves any such possibility. These algæ are so extremely plentiful in and around Brisbane during the summer months, that sometimes waterholes with Characeæ are far more common than waterholes without them, and opportunities for studying them in connection with mosquito breeding are never wanting. A minute examination of a chain of waterholes forming an arm of the Enoggera Creek was recently made in order to ascertain what aquatic life was likely to exist in and amongst the various species of Characeæ, which occur in such large quantities as to completely cover the floor of the waterholes.

The insect fauna of one waterhole is very much the same as another. Most of the predatory insects mentioned in this paper occur.

Culex annulirostris is always plentiful on these occasions and so is *Anopheles annulipes*. Both these mosquitoes shelter in and among the *Nitella*, and without some such shelter it is questionable whether these mosquitoes could exist at all in the face of all the various larval destructors which exist in one such waterhole. When once disturbed the larvæ of these mosquitoes can be located without any difficulty; they usually occur more frequently than not in association.

In view of these facts it is indeed strange that *Nitella phauloteles*, for one, should have been considered an effective larval destructor, for our observations go to show that, instead of destroying these sylvan mosquito larvæ, the plant tends to afford them necessary protection from their natural enemies. There are, of course, other sylvan mosquitoes which select these waters from time to time, at different periods of the year.

CANNIBALISTIC MOSQUITOES.

We have in Queensland several mosquitoes that are cannibalistic in the larval stage, and with their highly developed and formidable mandibles are capable of wonderful execution. Of these *Lutzia halifaxi* Theo., in polluted water; *Ædes (O.) vittiger* Skuse, in fresh water; and *Mucidus alternans* Westwood, in salt water, stand out in importance.

With regard to *Lutzia halifaxi,* it is a pity that it is not possible to utilise this species and turn its cannibalistic tendencies to a useful purpose in anti-mosquito work. Though this formidable insect breeds in the main in polluted water it does not bite under Australian conditions and is, therefore, quite harmless, but it has a distinctly seasonal occurrence in Brisbane and would therefore be only of small practical value.

Megarhinus speciosus Skuse is also cannibalistic in the larval state. This species is, however, for the greater part a breeder in tree cavities, and would therefore as such be of very little use biologically. It is not a plentiful mosquito, but there is no knowing what wonderful use might be made of this species under suitable conditions, and it is highly desirable that the question should be studied from this standpoint.

Wigglesworth[32] has a note in ''Nature'' with regard to *Megarhinus brevipalpis,* and suggests a means by which predaceous mosquitoes such as this might be introduced into distant countries with a minimum loss of life.

TADPOLES AND MOSQUITO LARVÆ.

Mosquitoes have many enemies other than fish which take considerable toll of the many different species, and to which some reference here is justified. It is, of course, somewhat difficult to substantiate all at once the numerous references to larval destructors which, in many cases, are based on popular ideas or mere hearsay, though possibly founded upon a truthful observance in the first place. There is for instance the question of frogs and frog larvæ. The author has seen on more than one occasion adult frogs snap at adult mosquitoes and devour them, but has never been successful in discovering whether tadpoles really devoured mosquito larvæ or not. Tadpoles are evidently vegetable feeders. There is no direct evidence in Queensland to justify the idea that they devour mosquito larvæ. Sometimes the absence of larvæ in waters frequented by frogs and their progeny seems fairly conclusive, and yet this is not the case in waterholes in which *Nitella* affords protection, for in such, sylvan mosquito larvæ may occur side by side with tadpoles in the same water. It is a common occurrence to find frogs in tree cavities resting with their bodies half in the water, but the numbers of larvæ of *Ædes notoscriptus* in such water do not seem to be any the less. Pruthi, writing from India, says that the tadpoles of the common frog *Rana tigrina* seem to be very fond of larvæ. He states that one full-grown tadpole can consume from fifteen to twenty-one larvæ in a period of twenty-four hours, but unfortunately I have no evidence of this sort to offer. On the contrary, the presence of numbers of tadpoles in water in which mosquito larvæ are known to occur is inexplicable unless the habit of eating mosquito larvæ is restricted to certain species only.

PREDATORY INSECTS.

Most predatory aquatic insects may be broadly classed as larval destructors.

Aquatic Hemiptera are Mosquito Destroyers.—Waters in which they occur are usually of a more persistent character. Mosquito larvæ as a rule are not plentiful where these occur, and yet, when the water is full of a fine vegetable growth such as is provided by various species of Charophytes, aquatic bugs act only as a check, not as a control. In the Brisbane district our Characeæ harbour and support a very large and varied number of small insect forms including mosquito larvæ, both Culicines and Anophelines. In such we frequently find these aquatic predatory insects in large numbers side by side with mosquito larvæ, a condition only possible when a considerable amount of food is available. For the rest *Nitella* proves such an effective harbour of refuge that larvæ of sylvan mosquitoes apparently hatch often without any interference from their natural enemies.

Super-Family Gerroidea.—This contains two families of water striders, the Gerridæ or Pond Skaters, and the Hydrometridæ known as Slender Water Striders. These are easily recognised as insects which slide along the surface film of the water in a series of jerks. Their interest lies principally in their diving habits for food; the eggs are laid on water weeds, *Nitella* being frequently selected for this purpose. There seems to be some doubt in the minds of certain entomologists as to the accuracy of the statement that these insects are known to be larval destructors, but the author of this paper has been able to secure definite evidence that these Hemiptera do eat mosquito larvæ when other suitable food does not seem to be available, and in this connection it is interesting to note that Pruthi[21] in India has made similar observations.

Super-Family Notonectoidea.—There are four important families belonging to this group, containing insects which are all of them effective larval destructors, as we can testify from personal observation.

Family Nepidæ—Water Scorpions.—These are fairly common insects, and various species occur in Brisbane, of which the following is only one—*Laccotrephes tristis* Stal. Members of the Nepidæ kill mosquito larvæ by piercing the skin with their rather delicate proboscis and sucking out the juicy contents. These rather sluggish creatures find no difficulty in procuring Anopheline larvæ for their prey.

Family Naucoridæ—Water Bugs.—These are often very plentiful, and in many respects resemble *Notonecta* in their habits. I have personally noted species of *Naucoris* darting at resting mosquito larvæ (sylvan), and dragging them under the surface of the water. They are also fond of Chironomid larvæ and pupæ.

FAMILY BELOSTOMATIDÆ.—The Giant Water Bug *Lathocerus indicus*, known locally as the "Fish Killer," is a member of this family. That certain members of this family devour mosquito larvæ is borne out by Pruthi. The author has no personal knowledge with regard to the ability of this giant bug to devour mosquito larvæ, and it is more than likely that this insect is far too big to bother about such small fry. I can only point out that Pruthi records his having seen this bug in his experimental jars devour four larvæ during a period of twenty-four hours.

FAMILY NOTONECTIDÆ—BACK SWIMMERS.—These predaceous insects are quite common in our area, and are very effective mosquito destroyers; it is a matter of common knowledge that they are carnivorous, and are very fond of a mosquito diet. The back of *Notonecta* is keeled, enabling it to swim on its back. Their eggs are laid on water plants.

SUPER-FAMILY CORIXOIDEA.—This possesses a single family—the Corixidæ—also called Water Boatmen, but differing from *Notonecta* in many important particulars. *Corixa* swims on its back, but is not keeled, the back is flat; they devour one another if food is scarce, and lay their eggs on water weeds. Certain algæ, probably of the *Nitella* type, provide them at times with food, for they occur very plentifully in such waters. Corixidæ kept in confinement devour mosquito larvæ with relish.

AQUATIC COLEOPTERA ARE MOSQUITO DESTROYERS.—It is probably true that most Coleopterous larvæ are larval destructors of importance.

SUPER-FAMILY CARABOIDEA.—Water beetles of the family Dytiscidæ are very numerous in our area. They can easily be detected, because both the larvæ and the imagines have to take air by rising to the surface of the water. *Cybister gayndahensis* Macl. is a common Brisbane species.

SUPER-FAMILY GYRINOIDEA.—To this belong the Gyrinidæ or Whirligig Beetles. These frequent fresh water, and make use of water weeds for laying their long, slender eggs. The larvæ of this family are extremely active and voracious; they possess powerful biting mandibles, which are capable of making short work of mosquito larvæ, especially of Anophelines, which live in the upper layers of the water. The eggs are laid in summer on the stems of aquatic plants, *Nitella* being frequently selected for this purpose.

SUPER-FAMILY HYDROPHILOEDEA.—The adult members of the family Hydrophilidæ are vegetarians, but the larvæ are predatory. This family contains many fine types quite common in our local waterholes. The larvæ are particularly vicious feeders, if one can judge by their methods of attacking their prey.

ORDER HYMENOPTERA.—There is a small "Policeman Fly," known as *Seriocophorus relucens* Smith, common throughout the Brisbane area, Queensland, and New South Wales generally, which can frequently be seen catching mosquitoes on the wing, and carrying them to its nest; it is not an uncommon thing to catch this Hymenopteron in the act. It belongs to the family of the Nyssonidæ. (Hamlyn-Harris.[12]) I had several such in my collection until the mites got them.

Order Diptera.—This order doubtless possesses various species of flies which also catch mosquitoes on the wing. One of these "robber" flies common along the coast and in Central Queensland is worthy of mention, namely, *Atomosia culicivora* White. Of the smaller robber flies several appear to be useful in this direction, and can now and then be taken with mosquitoes in their jaws. Dr. T. L. Bancroft, of Eidsvold, has made similar observations.

Australian Odonata.—In a paper of this sort it is quite sufficient to state that this order includes all those insects commonly known as Dragon Flies, which may be rightly described as the tyrants of the insect world. There is no doubt that they are amongst the most effective larval destructors we have, for not only do the adult dragon flies catch mosquitoes on the wing, but all the larval forms are known to destroy other insect larvæ which dwell in water weeds, which form a very profitable hunting-ground for all the members of this sub-order. Their persistent perseverance, which enables them to clear waterholes of all aquatic life, is truly wonderful. They are also very destructive to all small fish. In the laboratory they have been observed to destroy almost all small forms of aquatic life.

Larval Destructors in the Rice-Fields of New South Wales.—A recent visit to the Murrumbidgee Irrigation Area of New South Wales has enabled me to witness an immense number of larval destructors actually at work in the field. One cannot help being very much impressed with the extremely useful work that these creatures are doing in keeping a check on mosquitoes. Where mosquitoes did exist in their presence, the former were present only in very small numbers. Natural enemies in these waters consist for the greater part of *larval* forms of Hemiptera, Coleoptera, and Odonata. These on account of their great numbers constitute a very valuable check on mosquitoes in the rice-fields during the early stages of the rice's growth. Towards the end of the rice season, there is evidence, however, that mosquitoes become too plentiful for the larval destructors to cope with them.

HYDRA AS A CHECK UPON MOSQUITO LARVÆ.

Where these occur they are most effective mosquito destroyers. It has been the author's good fortune to feed *Hydra* on many occasions. The *Hydra* anchored against the side of the vessel catch the larvæ in their tentacles as they wriggle in the water, paralyse them almost instantaneously, and never relinquish their hold until the larvæ are dead or useless as food.

VORTICELLA.

Colonies of *Vorticella* are sometimes so plentiful that it is thought they exercise some check upon mosquito larvæ. In certain types of permanent pools they sometimes occur in large numbers. These pools are selected by Anophelines on account of their plentiful food supply. Such Anopheline larvæ examined have at times been so heavily infested that they have died before pupation. In Brisbane, *Anopheles annulipes* is the one usually attacked. The large numbers of *Vorticella* found more especially attached to the mouth organs and the breathing-tubes must, one would think, occasion the larvæ some considerable discomfort.

FRESH-WATER SNAILS.

Some of these grow very fond of mosquito eggs. Detailed observations with regard to the habits of snails as a whole have not been possible, but the author has observed *Bullinus pectorosus* Conrad feeding on eggs and egg-rafts on many occasions. If present in sufficient quantities, these snails will keep the surface of the water free of eggs all the time. The mysterious disappearance of eggs or their apparent inability to hatch has often been explained later by the habits of this small snail.

OTHER ENEMIES.

In addition to the above there are also birds, bats, and lizards, possibly mites, to say nothing of possible fungoid diseases, which may possibly be responsible for considerable mosquito reduction in nature, but of the results of which we are comparatively ignorant.

It is rather a curious thing that *Tæniorhynchus* (*Mansonioides*) *uniformis* Theo should be so frequently taken in Brisbane with mites attached to the lower end of the thorax. These mites are Hydrachnid larvæ, which apparently attach themselves to the mosquito before it leaves the water. Why these should select just one particular type of mosquito is curious. Out of every ten specimens taken, usually after heavy rains (1927-1928), more than half were parasitised, but I have no evidence to show that they are in any way inconvenienced thereby. (Consult Balfour,[7] Boyd,[8] Dye.[11])

LARVIVOROUS FISH.

It is only of comparatively recent date that mosquito control by the means of larvivorous fish has been taken seriously. It has of course been known for a very long time that mosquitoes form a regular part of the diet of certain fish, but, although some attention has been paid to fish suitable for mosquito destruction in this State, no attempt, as far as I know, has been made until quite recently, to give practical application to the knowledge gained.

Cooling's preliminary observations published in the Annual Report of the Commissioner of Public Health for Queensland, 1913, are of great value and undoubtedly form the basis of this work in Queensland. Since then no one seems to have done any independent work.

All our creeks and watercourses contain fish during the greater part of the year, and these small fish, of whatever species they are, effectively keep these streams clear of mosquito larvæ; but while there can be no doubt that larvæ-eating fish are of practical value under ordinary normal conditions in the field, they can be made of greater practical value under artificial conditions.

Fish control is, after all, confined to somewhat narrow limits, but within these limits it must be recognised that it can be made very valuable, and at times has been found to be the only practical method of control, and it is in view of these facts that their use on a larger scale is hereby strongly recommended. Under natural conditions fish are very frequently practically useless, owing to the fact that the fish cannot get at the larvæ which are protected by various kinds of aquatic and other vegetation. On the other hand some sort of proper protection is necessary if the smaller fish are to be safeguarded from the attacks of larger fish; that is why shallow water is a protection in itself, forming a natural sanctuary within its shallows.

Larvivorous fish are of special value in ornamental ponds and lakes in which the vegetation is under control, and it is a thousand pities that we have so few of these in Queensland. There seems a perfect mania for the destruction of ponds which, with very little trouble, could be converted into useful ornamental waters stocked with a fine assortment of suitable fish, as is the case in all the older countries of the world. Unfortunately, Queensland is very dry at times, and large sheets of water containing fish are apt to dry up.

FAMILY RETROPINNIDÆ.—*Retropinna semoni* Weber. (Fig. 1.) This smelt is a beautiful little fish plentiful at times in the Enoggera, Ithaca, and Moggill Creeks, where we have taken it in small comparatively shallow pools which are only connected with the waters of the main channel at flood-time. These fish, like *Craterocephalus fluviatilis*, which they resemble, are voracious devourers of mosquito larvæ, and where they exist are of even greater value than has hitherto been thought possible. The smelt is very rapid in its movements, and being capable of detecting adult mosquitoes on the water surface at some distance is particularly efficient. Its value in mosquito control consists in its love of roaming over large areas of waters if available, in its exceedingly rapid movements as a surface feeder, and its extreme fondness for mosquito larvæ.

FAMILY ATHERINIDÆ.—*Craterocephalus fluviatilis* McCulloch.—The Freshwater Hardyhead. (Fig. 2.)

Natural Habitat.—This fish occurs abundantly in freshwater streams and deep permanent waterholes. It is more abundant in the western rivers of New South Wales than in Queensland. Adults vary in size from 2 to 4 inches, and can be taken in the shallows along the banks often in very large numbers.

Natural Habits.—Its egg is an adhesive demersal one and relatively large. The spawning season is during the warmer months—a cold season retards development but its best spawning time is during October and November. The fish make no "nest" or "redd" as does the trout, but deposits its eggs in crevices between the rocks and on the clean rocky bed of the river in a shallow narrow stream, perhaps not more than 12 inches deep.

The Hardyhead is shy and very rapid in its movements, and unless it occurs in large shoals, as is frequently the case, it is not at all easy to catch. It is a true mosquito destroying fish and should be encouraged in every possible way. It is entirely suitable for use in a trout hatchery.

It occurs in numbers in the Reservoir at Enoggera. McCulloch has described a species from the Burdekin River which he named *C. maculatus,* but it is, I understand, a synonym.

Its Use in the Rice-fields of New South Wales.—This fish cannot be too highly recommended for mosquito work in the Murrumbidgee Irrigation Area of New South Wales. The actual difficulty might be to procure it in sufficiently large numbers to be effective, but as this fish lends itself particularly to stripping there should be no reason why large quantities of this Hardyhead should not be procurable. The breeding of these in hatcheries, if necessary, should not be either a difficult or an expensive item, and if large numbers could be introduced into the waters of the main canal, after leaving Berembed weir, they would gradually work their way through the irrigation area even as other fish are known to do at present. It is not an uncommon thing to see small fish swimming about in the rice-fields, but these are of no known value in mosquito control. It is a suggestion well worthy of the notice of the authorities concerned.

FAMILY MELANOTÆNIIDÆ.—*Pseudomugil signifer* Kner.—The Queensland Blue-eye. (Fig. 3.)

Natural Habitat.—Adults of this species which attain to 1½ or 2 inches in length are found very abundantly in all waters subject to tidal influence, but as it can adapt itself without any inconvenience to fresh water it is found also along the coastline in the rivers of Southern Queensland. The Blue-eye does not frequent polluted waters except temporarily in order to snatch such organic morsels of food as the water may yield at the moment. City drains provided with household refuse which empty into tidal channels attract sometimes large shoals of these fish. Fig. 4 represents such a city drain served by tidal waters; it shows a tendency to become polluted, causing Blue-eyes to feed here for the greater part of the year.

Natural Habits.—This small fish is an exceptionally efficient mosquito destroyer. On account of its size it is able to work its way to the very edges of the water, a habit which it has in common with tropical larvivorous fish. It is mainly a surface feeder and does wonderful work in controlling mosquitoes in all tidal waters.

MELANOTÆNIA NIGRANS Richardson.—The Crimson-spotted Sunfish. (Fig. 5.)

Natural Habitat.—This beautiful fish occurs under natural conditions in clear fresh water, avoiding dirty water except on rare occasions. The adult forms reach a length of about 2½ to 3 inches and occur in all fresh-water creeks and large waterholes periodically served by flood waters. Sunfish are sometimes trapped in waters unsuited to their natural habits, and occasionally they are to be found in waters supplied with local drainage in which they are only capable of living for a short time. A large batch recently found in a polluted waterhole yielded specimens all of which ultimately died through a heavy infestation of *Saprolegnia,* a fungus to which this fish is at times rather prone, particularly under such adverse conditions.

Natural Habits.—This fish does well in aquaria and after a time loses its shyness. It is undoubtedly one of the best of our larval destructors, and will feed not only on larvæ and pupæ but also on eggs and especially adults. It is by no means cannibalistic, for it seldom if ever will eat small fish either of its own or any other species. It will live quite peaceably side by side with Barbados Millions without making any attempt to eat the young *Lebistes.* This characteristic is of such tremendous advantage that it has been responsible for the selection of this fish for use in the Brisbane City Council's hatchery in South Brisbane. (Fig. 6.)

Fig. 7 shows a typical water frequented by these fish. It is a portion of Enoggera Creek on the Waterworks road. Here there occurs a copious growth of *Hydrilla verticillata* in which the majority of our Queensland larvivorous fish find harbourage and food.

Fig. 8 is a reproduction of a portion of the same creek separated in dry weather from the main stream, and used by the Queensland Spotted Sunfish for breeding purposes. This pool during the month of January 1928 was full of various aquatic plants, especially *Hydrilla* and *Nitella,* and hundreds of young Sunfish disported themselves in this sheltered spot. Such breeding places are, of course, by no means of a permanent nature but are dependent upon weather conditions. By the time the waters rise and flood such natural refuges, the fish are generally old enough to look after themselves. The eggs are probably pelagic, which would account for their being laid in safely protected waterholes.

Family Ambassidæ.—This family contains a number of fish probably extremely useful in mosquito control; in fact, it is not at all unlikely that every member of the genus is larvivorous. Only one, namely *Priopis olivaceous,* has been definitely described as a larval destructor, but it is very likely that *Ambassis agassizi* Steindachner (South-east Queensland, &c.), recorded from inland creeks, may be equally effective. The Yellow Perchlet, *Priopis marianus* Gunther, recorded from the Mary River and Moreton Bay, should be capable of doing good work in salt or brackish water. The whole genus requires closer investigation from this standpoint.

Priopis olivaceous Ogilby.—The Green Perchlet. (Fig. 9.)

Natural Habitat.—This fish prefers clean deep water, where large schools are generally found. Small batches occur in shallow waters in company with other types of fish. The Perchlet does not favour polluted though it is sometimes found in muddy waters.

Natural Habits.—Though this fish is extremely voracious, it has from the mosquito standpoint the fault of being cannibalistic. When hungry the Perchlet will devour any fish small enough that comes within its reach. In captivity it is cannibalistic, at all times, provided the opportunity is given. It lays floating eggs among vegetation and is on the whole rather shy. We have never been able to get it to breed in captivity.

FAMILY ELEOTRIDÆ.—The three Gudgeons here referred to all belong to the same family and are not dissimilar in their habits. As the fish of the larger species reach maturity they tend to develop a cannibalistic tendency. They prefer the coarser food available at the bottom of a pool or creek to the mosquito larvæ which frequent the surface layers of the water, and will devour the smaller fish of their own as well as those of other species when procurable. Instances are on record of the Carp and Trout Gudgeons completely wiping out the smaller Fire-tailed Gudgeons, and observations go to show that the latter fish avoid unnecessary proximity to the former as a matter of expediency. These gudgeons cannot be classed as truly larvivorous though they are larva-eating fish, which is a different thing, however. It is a question whether they exercise any appreciable mosquito control except perhaps where they occur in such overwhelming numbers that mosquito larvæ must necessarily form a part of their daily diet; but as larvæ-eating fish they have their value.

MOGURNDA (MOGURNDA) ADSPERSUS Castelnau.—The Trout Gudgeon. (Fig. 10.)

Natural Habitat.—The Gudgeons are all bottom feeders, and occur at times together in large numbers, but at other times each different species is found by itself. The distribution of the Trout Gudgeon, according to Cooling, is said to be from the Fitzroy River, in the north, to the Upper Shoalhaven district in the south. It occurs in all waters frequented by other larvivorous fish, with the exception, perhaps, of the Blue-eyes, but is less noticeable, especially during the cooler weather, when in common with other Gudgeons it hides itself in the mud or vegetable-matter at the bottom of the water until the spring calls it forth to breed.

CARASSIOPS COMPRESSUS Krefft.—The Carp Gudgeon. (Fig. 11.)

Natural Habits.—The remarks made with regard to the Trout Gudgeon also apply to this fish, which does not, however, consort with them for choice. It does not grow as big as the Trout Gudgeon, and is on the whole less fierce in its methods of attack.

CARASSIOPS GALII Ogilby.—The Fire-tailed Gudgeon. (Fig. 12.)

Natural Habits.—This small gudgeon is the most useful of the three, but though very common in the whole eastern portion of Queensland, does not occur in such large numbers as the other two gudgeons do. It is to be found in fresh-water creeks and in any backwash, as well as in large waterholes usually of a shallow nature. Being of a small size (adults rarely exceed 2 inches), it is preyed upon by the larger specimens of fish, and consequently it likes to isolate itself in large shoals in out-of-the-way potholes of watercourses, where in fairly deep water provided with plenty of aquatic weeds it disports itself and breeds.

CARASSIOPS KLUNZINGERI Ogilby.—This fish is very closely allied to the Carp Gudgeon, and is reported from the Burnett River district as a valuable mosquito fish. (Dr. T. L. Bancroft.) We have no knowledge of its occurrence in the Brisbane area.

FAMILY THERAPONIDÆ.—*Therapon unicolor* Gunther is an excellent mosquito fish. (T. L. Bancroft.) Unfortunately, it has not as yet been recorded from the Brisbane district, but it seems fairly plentiful north of the Mary River.

OTHER FISH SUITABLE FOR SALT-WATER CONTROL.

BUTIS AMBOIENSIS Bleeker.—Closely related to these Gudgeons there is a salt-water species occurring in the Brisbane and other tidal rivers of Southern Queensland known as *Butis amboiensis,* which we have reason to believe is also a larval destructor of some importance. The total absence of mosquito larvæ in the tidal creeks in which these fish occur seems to supply sufficient evidence of their activities, and one is inclined to think that there exist in our tidal creeks sufficient quantities of larval destructors to prevent mosquitoes occurring anywhere. This is of immense value in mosquito control, because it is realised that if tidal waters can be given an unrestricted passage to work their way to and fro without let or hindrance, and in or out of potential breeding-places, swamps and the like, then the control of such areas must be rendered comparatively simple. Brisbane waters do not possess the various species of Killifishes so successfully used in combating salt-marsh mosquitoes in New Jersey, but we believe that there are quite a number of other fish which might be successfully used in Queensland, and even now are probably instrumental in controlling such waters in which they occur.

FAMILY GOBIIDÆ—*Rhinogobius leftwichii* Ogilby.—This fish, of which an illustration is given in Fig. 14, occurs in salt-water tributaries of the Brisbane River, such as the Norman Creek, and assists in mosquito control in tidal waters generally. This we believe to be the case, because when kept in confinement, this fish proves itself an extremely efficient larval destructor.

MUGILOGOBIUS DEVISI Ogilby. (Fig. 13.) Occurs in salt-water and finds its way up the creeks of Brisbane under tidal influence. It can be accustomed to fresh water, and is known to devour mosquito larvæ voraciously. The eggs of both these species are hung on various substances, where the male guards them against the possible attack of enemies.

FAMILY MUGILIDÆ.—*Mugil cephalus* L., the Sea or Mangrove Mullet, has been said by some to be larvivorous. I have kept specimens of young in aquaria, but not under any circumstances could these fish be induced to take any notice of mosquito larvæ.

TRUE LARVIVOROUS FISH INTRODUCED INTO AUSTRALIA.

FAMILY PŒCILIDÆ—*Lebistes reticulatus.*—"Barbados Millions," sometimes called the Opal Fish. (Figs. 16 and 17.)

Lebistes will thrive under cover, in well-balanced aquaria, provided with a thick aquatic vegetation. The chief objection to its introduction into the open in Southern Queensland lies in its inability to stand sudden changes in temperature, but for all that it can be made to have its uses, and will winter safely among copious aquatic growth. This fish is viviparous and a very prolific breeder, and when hungry will sometimes eat its own young. Plenty of thick weeds are necessary in order to enable the young to hide. *Ceratophyllum demersum* is ideal for this purpose, though a combination of *Hydrilla verticillata* and *Valisneria spiralis* proves ideal.

This small fish wintered in the evaporation tank shown in Fig. 15 quite satisfactorily, in spite of the low temperatures to which the tank was subjected in 1928. Its ability to do this is evidence of its usefulness.

Restocking of such places as these, in case of accidents, is made quite easy by carrying over stock broods for use in the following spring. This method of control has been very successfully employed in anti-mosquito work in the Brisbane area.

Gambusia affinis.—The American Top Minnow. (Figs. 18 and 19.) These fish will thrive in fresh or brackish water, but cannot live in polluted waters. They can be accustomed to salt water without any harm. *Gambusia* is a surface feeder, and lives and thrives under a variety of conditions, but cannot stand sudden changes of temperature. Its original home is in the Mississippi Valley. *Gambusia* is well known to aquarium lovers, and thrives in Brisbane even in the winter, so long as the water in which it lives is not subjected to any sudden drop in temperature. The fish will not, however, survive the winter in small aquaria, unless provided with copious quantities of aquatic vegetation. It is a prolific breeder, and is viviparous. Young begin to make their appearance in Queensland soon after the warmer weather of spring has set in. If plenty of food is not available, they will eat their young without compunction.

The introduction of *Gambusia* into southern waters in Queensland seems to be fraught with some degree of risk, more particularly on account of the temporary nature of many waters, and the various natural and other enemies to which it is prone. During the summer months, however, in controlling local waters it is to be highly commended, and the carrying over stock brood for use in the following spring should make this method of control of ornamental waters very popular. In Northern Queensland this fish should be popular, and it is hard to see why it could not thrive there equally as well as it does in other tropical places of a very similar temperature.

It has been constantly argued that *Gambusia* cannot stand any degrees of frost, but we have reason to believe that this is not so. Some mosquito work recently conducted in Albania by Mrs. Sidney Loch is interesting. It transpired that the fish stood 10 degrees below zero, whilst 3 inches of ice was formed over the ponds. As long as air-holes were kept open there were apparently no losses at all. In the cold weather the fish disappear into the mud at the bottom, and though they are very lethargic and eat very little, if at all, during the winter, they become very lively as soon as the ponds are cleared of ice. With the approach of summer they fed heavily on powdered oven-dried bread and powdered sun-dried meat, and thus learnt very quickly to adapt themselves to local conditions.

HATCHERY.

Figure 6 gives a very fair impression of the hatchery which has been started in connection with the Brisbane City Council's mosquito work. A large cement tank has been converted into an aquarium, and at present the Crimson-spotted Sunfish disport themselves in its waters. The aeration of the water is carried out mainly by the following plants rooted in a sandy bottom some 6 or 8 inches in depth:—(1) *Hydrilla verticillata* (Water Thyme); (2) *Ceratophyllum demersum* (Hornwort); (3) *Chara fragilis.*

A number of young have hatched out this season, but it is hoped that when the fish have become better established they will feel so thoroughly at home that greater progress than has been possible up till now will be made. Such large aquaria can be used to good effect for other than Sunfish, but it seems unwise to mix the fish in view of the possible development of cannibalistic tendencies. In most outdoor aquaria, much damage is done by the presence of dragon fly larvæ. No fish-eggs are safe where these larvæ exist. We have found that large numbers of dragon flies haunt our hatchery. Sunfish are useful in keeping these natural enemies under control. It has been observed that, in aquaria where sunfish are, no young dragon fly larvæ can exist for long. The Crimson-spotted Sunfish is particularly suitable for the type of work for which it has been selected.

CONCLUSIONS.

(1) The value of biological control of mosquitoes must not be overlooked. With the increase of our knowledge the subject assumes daily greater importance, and it is with the hope that some day it may come into its own that these observations are herein recorded.

(2) Close observations made during the last three years show conclusively that larval destructors are capable of exercising more than a mere check on mosquito larvæ.

(3) Larval destructors occur in very large numbers in natural waters. They abound in almost prodigious numbers in waterholes which form a portion of the bed of our local creeks isolated from the main stream in periods of dryness. They occur further in artificial waters of various kinds, where they particularly during the early part of the season are instrumental in keeping mosquitoes completely under control. Conditions exist which make larval destructors in some natural waterholes effective throughout the whole year.

(4) Particular attention is here drawn to the beneficial effects of the larval destructors in the Murrumbidgee Irrigation Area of New South Wales, where the numbers appear to be even greater than in the Brisbane district, the presence of large numbers of Chironomids providing them with large quantities of natural food for months in the year.

(5) We are very fortunate in having quite a large number of larvivorous fish in Southern Queensland capable of doing wonderful work

both in fresh, brackish, and salt water. Among these the species most highly recommended are—*Craterocephalus fluviatilis* and *Melanotænia nigrans* for fresh water, and *Pseudomugil signifer* for brackish and salt water. A distinction is drawn between larvivorous as surface feeders and larva-eating fish as bottom feeders.

LITERATURE REFERRED TO.

It is not intended that this list should be a complete bibliography of the subject. Reference is made to such works as have an actual bearing on the subject as it concerns Queensland and were available to the author.

1. Balfour, A.—Mites on Mosquitoes. Journ. R.A.M.C., xl., 1923, pp. 122-127.
2. Ballow, H. A.—Millions and Mosquitoes. Imperial Dept. Agriculture, West Indian Bull., West Indies.
3. Barber, M. A.—The Effect of *Chara robbinsii* on Mosquito Larvæ. P.H. Reports, vol. 39, pp. 611-615, Washington, D.C.

   The author suggests that food requirements of the larvæ should be taken into consideration.
4. Barber, M. A., and King, C. H.—The Tadpole of the Spadefoot Toad an Enemy of Mosquito Larvæ. Publ. Hlth. Rep., xlii., No. 52, pp. 3189-3193, Washington, D.C., 30th Dec., 1927.
5. Barney and Anson.—Relation of certain aquatic plants to Oxygen supply and to capacity of small ponds to support the Top Minnow (*Gambusia affinis*). Proc. Ann. Fisheries Soc., 1920.
6. Barney and Anson.—Seasonal Abundance of the mosquito-destroying Top Minnow (*Gambusia affinis*) especially in relation to male frequency. Ecology, vol. ii., No. 1, Jan. 1921.
7. Barney and Anson.—Seasonal Abundance of the mosquito-destroying Top Minnow (*Gambusia affinis*) especially in relation to fecundity. The Anatomical Record, vol. 22, No. 5, Dec. 1921.
8. Boyd, J. E. M.—On the Incidence of Mites on Mosquitoes. Journ. R.A.M.C. 38, No. 6, pp. 459-460, 1922.
9. Cooling, L. E.—Annual Report of the Commissioner of Public Health, Queensland, July 1913.
10. Cooling, L. E.—Australian Fish as Mosquito Larvæ Destroyers. Health, vi., No. 1, pp. 11 and 12, Melbourne, Jan. 1927.
11. Dye, W. H.—Parasitic Mites on Mosquitoes. Journ. Roy. A. Med. Corps, Feb. 1924, fol. 42, No. 2, pp. 87-102.
12. Hamlyn-Harris, R.—Mosquito Survey Report No. 5. Australian Hookworm Campaign, Brisbane, April 1924.
13. Hegner, R. W.—The Inter-relations of Protozoa and the Utricles of Utricularia. Biol. Bull. 1, No. 3, pp. 239-270, June 1926.
14. Hilderbrand, S. G.—Top Minnows in relation to Malaria Control, with notes on the habits and distribution. Pub. Health Bull. No. 114, Washington, May 1921.
15. Hilderbrand, S. G.—A Study of the Top Minnow (*Gambusia Holbrooki*) in relation to Mosquito control. P.H. Bull. No. 153, May 1925, Washington.
16. Howard Dyar and Knab.—The Mosquitoes of N. and C. America and the West Indies; Washington, 1912.
17. Jordan D. Starr.—The Mosquito Fish (*Gambusia*) and its relation to Malaria. Smithsonian Report for 1926, Washington, pp. 361-368.
18. Lamborn, W. A.—The Habits of a Dipteron predaceous on Mosquitoes in Nyasaland. Bull. Ent. Res. xi., Part 3, pp. 279-281, Dec. 1920.
19. Macgregor, M. E.—The Influence of the Hydrogen Ion Concentration in the development of Mosquito larvæ. Parasitology, vol 13, No. 4, Nov. 1921.

20. McCulloch, A. R.—Notes on some Australian Atherinidæ. Proc. Roy. Soc. Q'land, vol. 24, 1913.

21. McCulloch and Ogilby.—Some Australian Fishes of the Family Gobiidæ. Rec. Australian Museum, vol. xii., No. 10, 1919.

22. McCulloch and Whitley.—A List of the Fishes recorded from Queensland waters. Memoirs of Queensland Museum, vol. viii., pt. ii., 1925.

23. Morishita, A.—Notes on the Natural Enemies of Mosquitoes. Dept. of Hygiene, Govt. Res. Inst., Formosa, 1926.

24. Pruthi, Hem Singh.—Some Insect and other Enemies of Mosquito Larvæ. Indian Jl. of Med. Res., vol. xvi., July 1928.

25. Rockefeller Foundation.—The use of fish for Mosquito Control. Rockefeller Foundation, 1924.

Has an excellent Bibliography of 217 authors.

26. Seale, Alvin.—The Mosquito Fish (*Gambusia affinis*) in the Philippine Islands. Phil. Journ. Science, Manila, 1917, vol. 12, D. Section, No. 3.

27. Seymour Sewell and Chandhuri.—Indian Fish of proved Utility as Mosquito Destroyers. Indian Museum Publication, 1912.

28. Shaw, F. R.—Effects of Temperature on Aquatic Life in Cisterns. Pub. Hl. Bull., No. 156, pp. 65-71, Washington, D.C., Aug. 1925. (Reprinted June 1927.)

The ability of *Gambusia* to withstand cold is here pointed out. A reference is made also to the Musk Turtle feeding on mosquito larvæ.

29. Speer, Alma I.—Compendium of the Parasites of Mosquitoes (Culicidæ). Hyg. Lab. Bull. No. 146, U.S. Publ. Hlth. Service, Washington, 1927.

30. Stead, D. C.—Fishes as Mosquito Destroyers in New South Wales. Agric. Gazette of N.S.W., vol. xviii., Pt. 9, Sept. 1907, p. 762.

31. Van Dine, D. L.—The Introduction of Top Minnows into the Hawaiian Islands. Press. Bull. No. 20, 1907, Hawaii Agr. Exp. Stn., Honolulu.

32. Wigglesworth, V. B.—Delayed Metamorphosis in a Predaceous Mosquito Larva and a possible practical application. Nature, cxxiii., No. 3088, p. 17, London, 5th January, 1929.

33. Yablokov, N. A.—Little-known Enemies of *Anopheles* Larvæ. Russ. Hydrob. Zs. v., No. 7-9, — 194, 195, 4 refs., Saratov, July-Sept. 1926.

This paper is unfortunately not available to the author. A recent review, however, states that Anopheline larvæ in an aquarium were very extensively preyed upon by *Hydra fusca* L., and leeches are also referred to as a factor in natural control.

Additional References.

34. Brocher, F.—A propos de la capture de larves d'Anopheles par les Utriculaires. Amn. Parasit. hum. and comp., v., No. 1, pp. 46-47, 1 ref., Paris.

Refer also to the Review of Applied Entomology B13-170 in connection with two papers by Brumpt and Langeron on the capture of mosquito larvæ by the bladders of aquatic plants of the genus Utricularia.

35. Hamlyn-Harris, R., and Smith, Frank.—On Fish Poisoning and Poisons employed among the Aborigines of Queensland. Mem. Q'land Museum, vol. v., 1916.

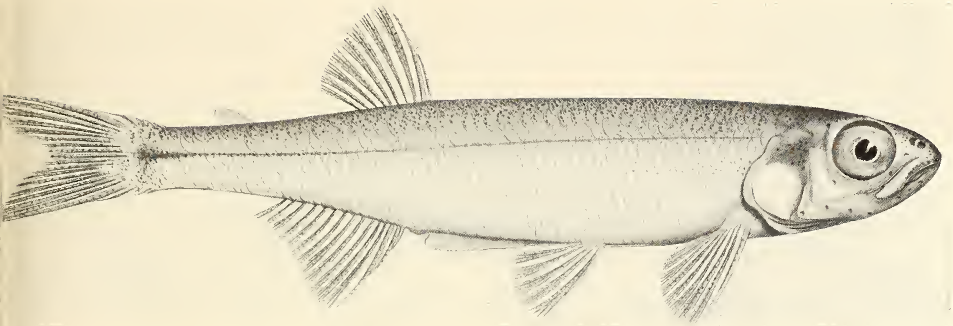

Fig. 1.—*Retropinna semoni* Weber. An effective mosquito destroyer common in Brisbane waters.

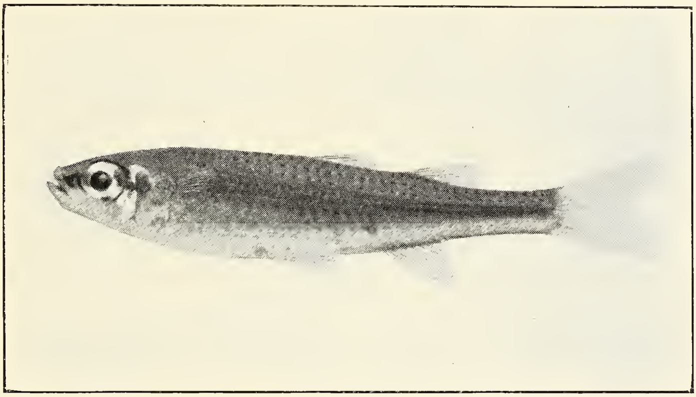

Fig. 2.—*Craterocephalus fluviatilis* McCulloch.—The Fresh-water Hardyhead. One of the most useful destructors Australia possesses.

Most of the fish shown in these illustrations are from photographs taken *in life*. Some difficulty was experienced in doing this, and it may be of interest to our readers to know what method we adopted.

A solution of 2 per cent. cocain hydrochloride was prepared in 50 per cent. alcohol, and small drops of this were added to the water in which the fish were placed. As the drug began to take effect slowly the fish would come to lie on their sides with fins extended in a very natural position, and, by carefully manipulating the camera from above, excellent pictures can be taken of natural history objects in this way.

The fish can be restored to a normal condition again by being placed in fresh water. By changing the water several times no ill effects seem to accompany the narcotisation, provided that the process is not unduly hastened or prolonged.

Figs. 2, 3, 5, 9, 10, 11, 12, 16, 17, 18, 19 *taken from life* by Mr. H. W. Mobsby, to whom our thanks are due.

Figs. 1, 13, and 14 kindly loaned by the Trustees Australian Museum.

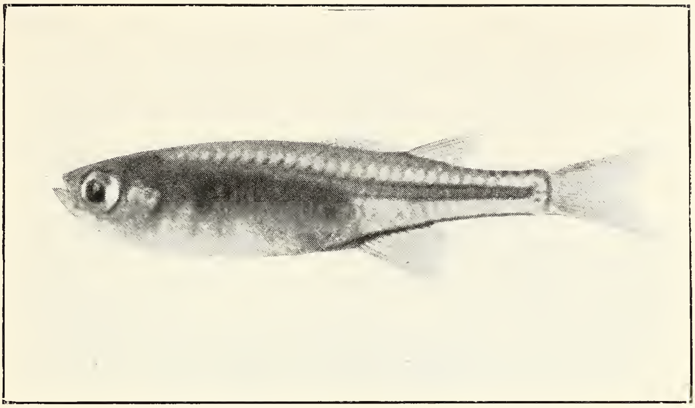

Fig. 3.—*Pseudomugil signifer* Kner. The Queensland Blue-eye. Efficient in either salt, brackish, or fresh water.

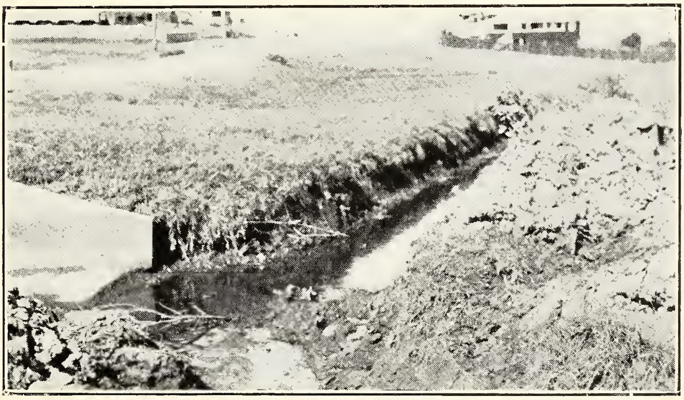

Fig. 4.—A Tidal Drain. A common feeding ground for Blue-eyes.

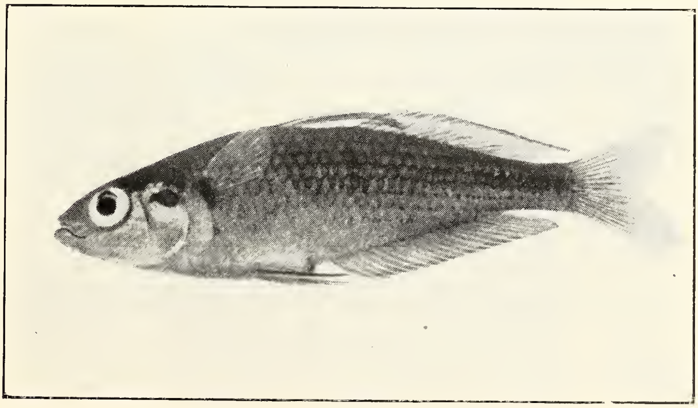

Fig. 5.—*Melanotænia nigrans* Richardson. The Crimson-spotted Sunfish. Queensland's most useful larvivorous fresh-water fish.

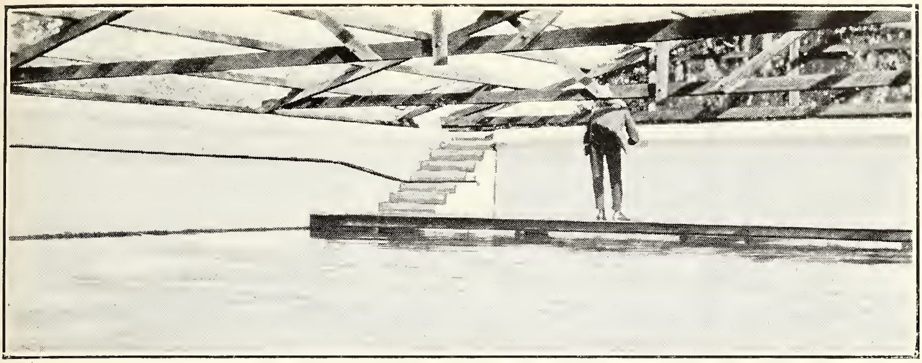

Fig. 6.—The western end of the Hatchery, situated in South Brisbane, the property of the Brisbane City Council, where the water is 4 ft. 6 in. in the deepest part. Here the Crimson-spotted Sunfish is breeding and flourishing.

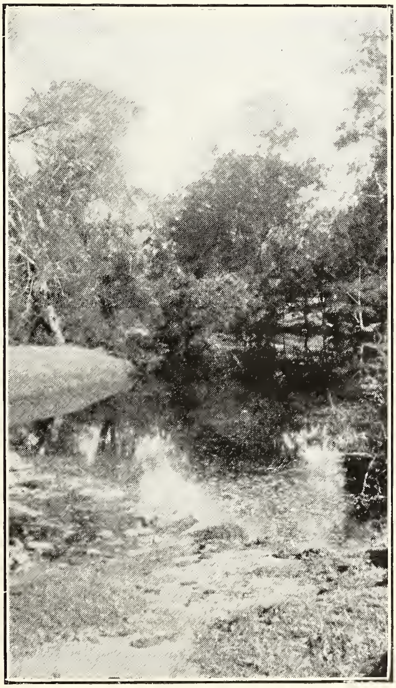

Fig. 7.—A portion of the Enoggera Creek. A natural home of various kinds of larvivorous fish.

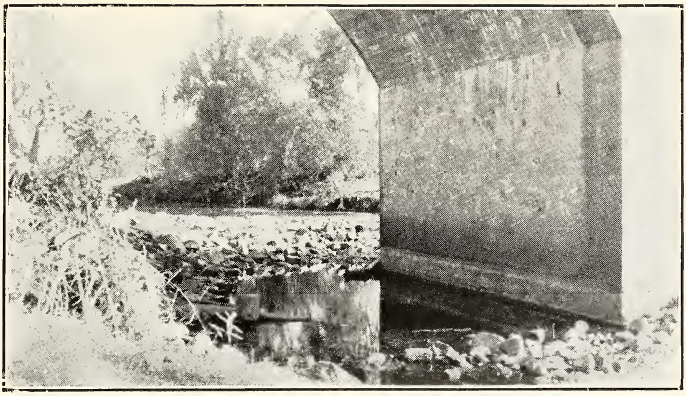

Fig. 8.—A quiet breeding pool of the Crimson-spotted Sunfish.

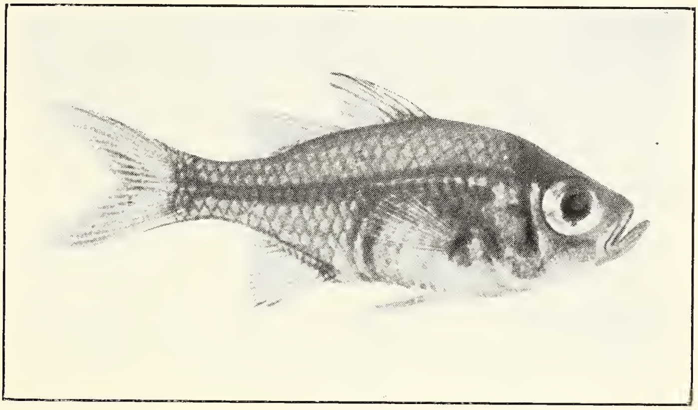

Fig. 9.—*Priopis olivaceous* Ogilby. The Green Perchlet, a larvivorous fish with cannibalistic tendencies.

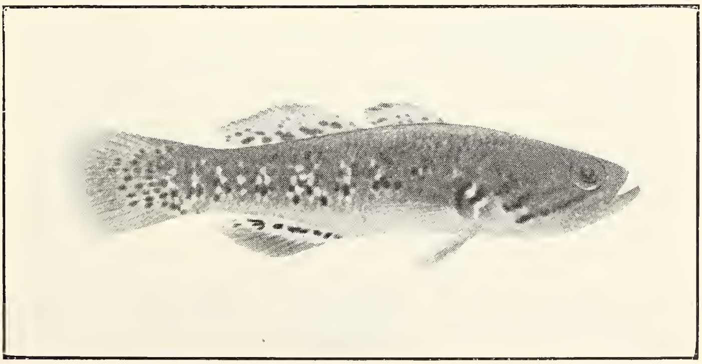

Fig. 10.—*Mogurnda Mogurnda adspersus.* The Trout Gudgeon, a coarse bottom-feeder.

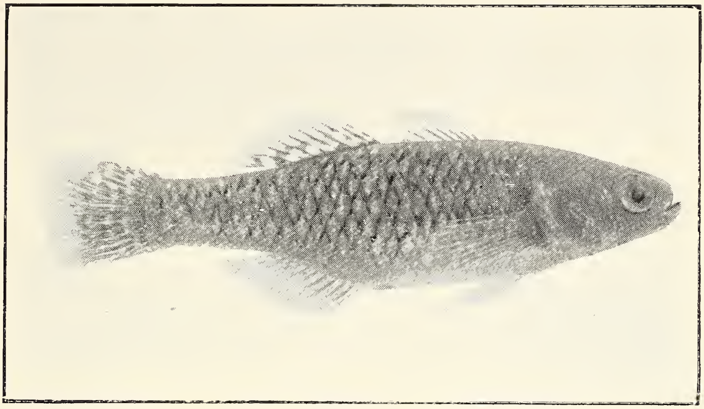

Fig. 11.—*Carassiops compressus* Krefft. The Carp Gudgeon (female). An active bottom-feeder of a voracious type.

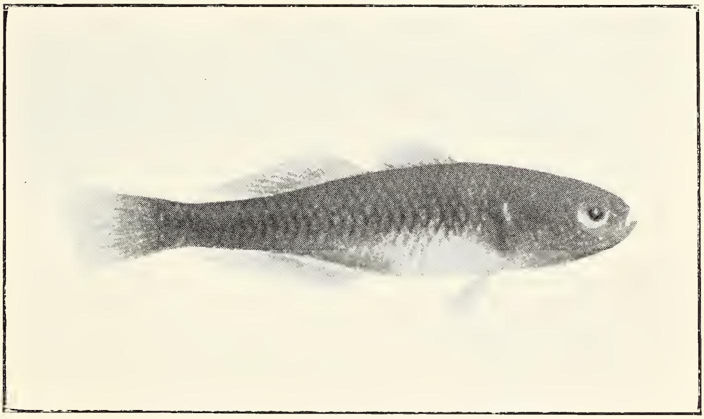

Fig. 12.—*Carassiops galii* Ogilby. The Fire-tailed Gudgeon.

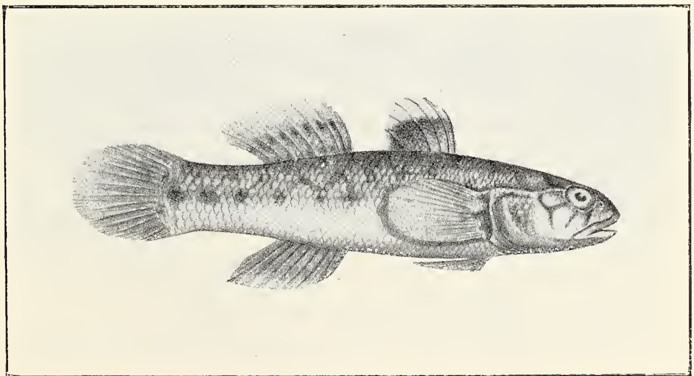

Fig. 13.—*Mugilogobius devisi* Ogilby. Suitable for mosquito control in tidal waters.

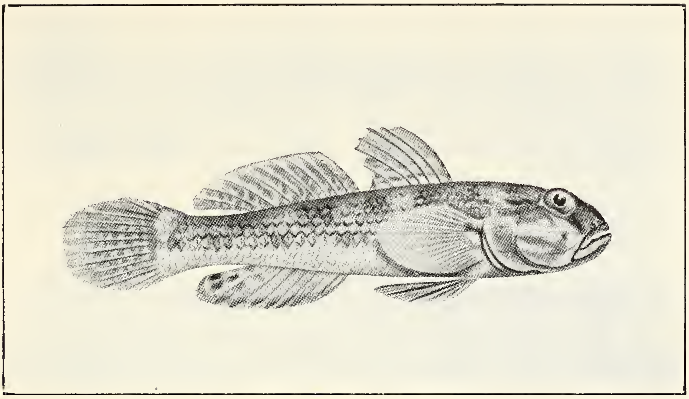

Fig. 14.—*Rhinogobius leftwichii* Ogilby. Useful for salt-water control.

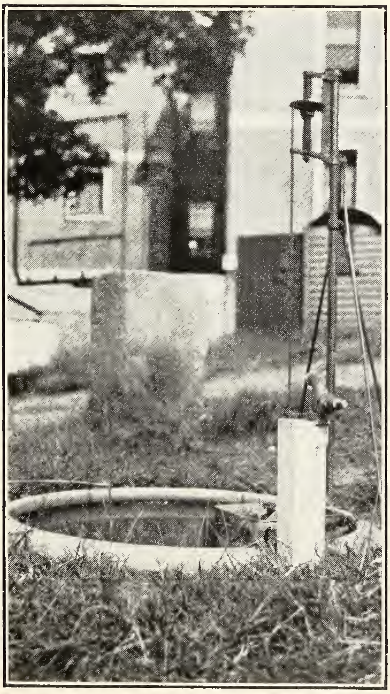

Fig. 15.—An Evaporation Tank entirely controlled by *Lebistes reticulatus*.

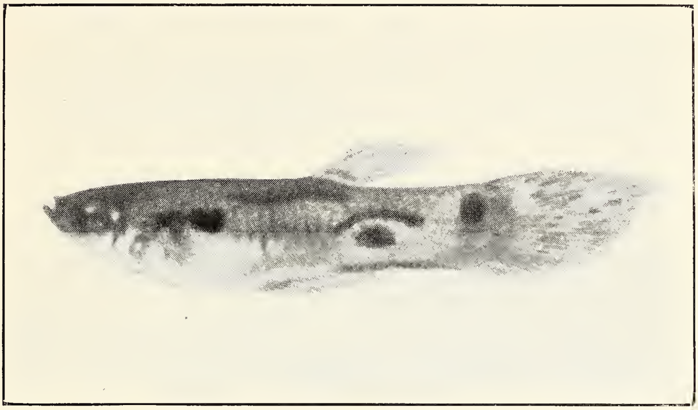

Fig. 16.—Male of *Lebistes reticulatus,* 1 in. in length.

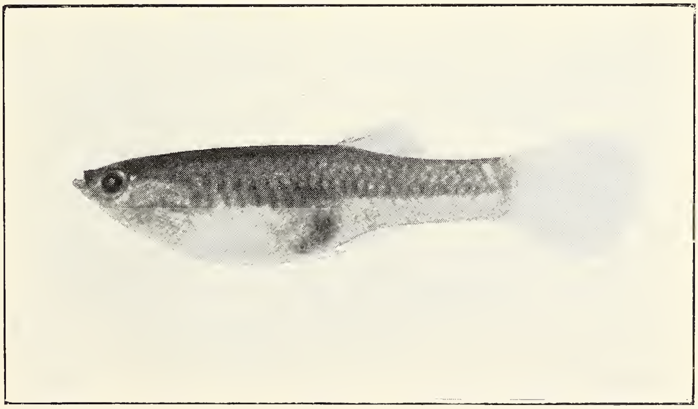

Fig. 17.—Female of *Lebistes reticulatus,* 1½ in. in length.

Cyprinodontidæ (Top Minnows). Small fish which always feed near the surface. They possess the lower jaw elongated and the top of the head flattened, making them particularly suited to surface feeding.

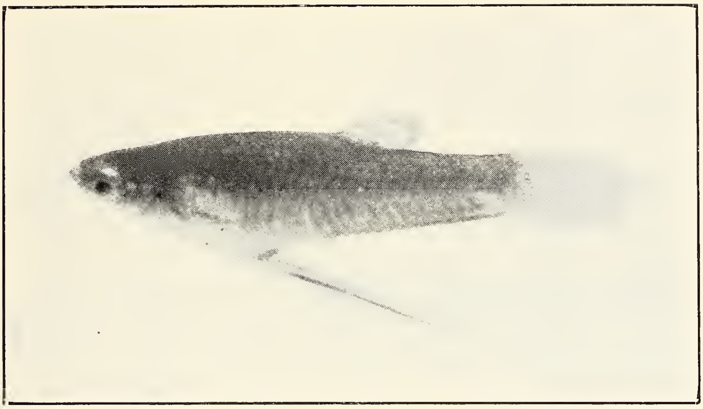

Fig. 18.—Male of *Gambusia affinis,* about 1 in. in length.

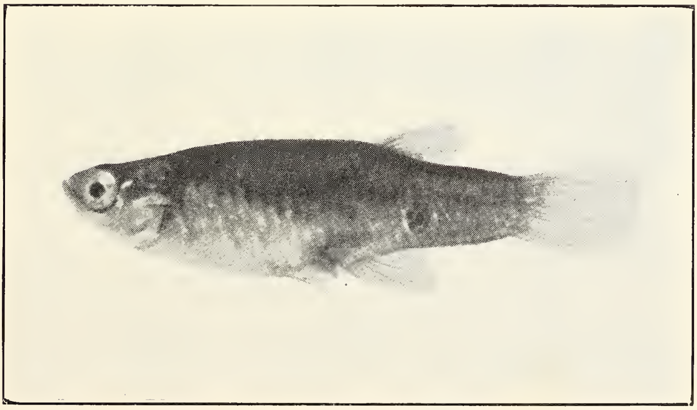

Fig. 19.—Female of *Gambusia affinis,* $2\frac{1}{2}$ in. in length.

A Revision of the Queensland Bignoniaceae.

By C. G. G. J. VAN STEENIS, Botanist at the Herbarium at Buitenzorg, Java.

Two Text-figures.

(*Communicated to the Royal Society of Queensland by C. T. White, 27th May, 1929.*)

Though the Bignoniaceæ of Queensland have been established for the greater part by F. von Mueller, Bentham, and Bailey, it appeared that several additions could be made after a revision of the material preserved in the Brisbane Herbarium. I am much indebted to Mr. C. T. White, Government Botanist, who kindly put these specimens at my disposal.

Most of the species had to be cited under new combinations, in which I have followed the international rules as now adopted.[1]

Tecoma has been worked out by Schumann[2] and by Bureau and Schumann[3]; they have pointed out that the true Tecomeæ are all trees with digitate leaves, and American in distribution.

Diplanthera is a name used for a potamogetonaceous genus by Thouars[4] four years before R. Brown published this name for the bignonian tree. So *Deplanchea* Vieillard has to be accepted, already used in Australian literature by F. von Mueller in his second Systematic Census of Australian Plants.

Haussmannianthes is a new name proposed for *Haussmannia* F.v.M. on account of the 9th main rule for botanic nomenclature,[1] which dictates that " the rules and recommendations of botanical nomenclature apply to all classes of the plant kingdom, recent and fossil, with exceptions which are expressly specified." O. Posthumus[5] in his article on *Dipteris novo-guineensis* called the attention to the eldest name *Haussmannia* Dunker (1846) of a fossil genus of Dipterideæ which has priority. This genus may be united later on with *Dipteris* but for the present it still exists.[6] The fact that *Haussmannia* F.v.M. is written with two s's and *Hausmannia* Dunker with only one does not allow the use of both of them for different genera.

[1] International rules of botanic nomenclature adopted by the international botanical congresses of Vienna (1905) and Brussels (1910).

[2] In Engler and Prantl, Nat. Pfl. Fam. iv., 3b (1896).

[3] In Martius Flora Brasiliensis, viii., pars 2 (1896-97).

[4] *See* Engler and Prantl, Nachträge zum, ii.-iv., Teil (1897) 37.

[5] In Recueil des travaux botaniques néerlandaises, 25a (1928) 248.

[6] Richter, Die Gattung Hausmannia, Leipzig (1906).

Further I had to pay attention to *Pandorea pandorana* (= *australis*), an extremely variable species, occurring from Lombok (Lesser Sunda Islands) and New Guinea along the eastern part of Australia as far as Tasmania. Bailey[7] gave three forms for the convenience of Queensland botanists. Indeed one may distinguish several forms, for the greater part due to the extremely variable climatic conditions under which the species grows, the species occurring in the lowland as well as in the mountains, and in dry country as well as in humid forests. The more material I examined the more I was convinced that it is certainly a single species, all intergrades between the extreme forms being present. This especially appeared after studying the many specimens present in the Brisbane Herbarium.

Not long ago Skeels has used the combination *Tecoma pandorana* for this species, the specific name of Andrews having the priority before *australis* of R. Brown. As mentioned above the genus *Tecoma* in the sense of Bentham and Hooker is composed of heterogeneous elements, and *Tecoma* has been limited to American trees with digitate leaves. Further I have reduced to it *Pandorea ceramensis* from the Moluccas and *Pandorea Poincillantha* from New Guinea, so that it ranges from the Moluccas and Lombok over New Guinea and Eastern Australia as far as Tasmania.

New Zealand is not inhabited by any bignoniaceous plant. New Caledonia has several, viz., *Dolichandrone* (1 sp.), *Deplanchea* (3 sp.), and *Pandorea* (1 sp.) as pointed out below. The Fiji Islands also seem to have one, viz., *Tecoma filicifolia* Nicholson (Dict. Gard. 4 (1887) 13), which, however, may be a cultivated one, introduced from America, and not a local endemic.

In phyto-geographical respect it may be of interest to pay attention to the fact that in the Queensland Flora nearly all the Bignoniaceæ of the whole of Australia are represented. They occur for the most part in the eastern part of the continent, or, which is much the same, in the more or less humid portions. The only species known from the drier areas in the North are the three cited Dolichandronæ, and justly these species show an undoubtedly xeromorphic structure. They are small crooked or scrubby trees with reduced leaf-surface. The nervature is an almost curious one in respect of all other Bignoniaceæ I know. The main nerve has nearly disappeared and the primary nerves are not distinct. Moreover, the leaves and leaflets are coriaceous in contrast with the other members of this East Asiatic genus, and the phyllotaxis is quite different from that of the other species. One may meet with opposite leaves as well as whorled and scattered ones, rather rare characters in Bignoniaceæ.

As to the relations with the surrounding countries, New Caledonia and New Guinea show the nearest connection with Queensland, the former country, however, being most related with New Guinea and both differing from Queensland by the occurrence of the wide-spread *Dolichandrone spathacea* (L.F.) K. Sch., a littoral species known from the Deccan Peninsula throughout the Malayan region to New Guinea and New Caledonia. It

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[7] Queensland Flora, 4 (1901) 1133-1137.

occurs throughout the southern part of New Guinea but has not been observed even in Thursday Island and other islands of Torres Strait in Queensland territory. On the other hand none of the xerophytic Queensland species has been found in New Guinea nor in New Caledonia, though e.g. *D. alternifolia* has been collected in Thursday Island. The aberrant Australian forms, isolated from the other Dolichandronæ in geographical and morphological respect, I have united formerly in the subgenus *Coriaceæ* V. St.

The two figures have been drawn by the Javanese draftsman Sandiwirio of the herbarium at Buitenzorg.

I have cited also the material I saw in non-Queensland herbaria, this being the more necessary as several other localities can be included in this way.

The following abbreviations have been used for denoting the herbaria of which I had the opportunity to study a smaller or greater number of specimens :—

H.B. = Herbarium of the Botanic Gardens, Buitenzorg (Java).
H.Br. = Herbarium of the Botanic Gardens, Brisbane.
H.K. = Herbarium of the Botanic Gardens, Kew.
H.L.B. = The State Herbarium, Leyden (Holland)
H.P. = Herbarium of the Museum d'Histoire Naturelle, Paris.
H.S. = Herbarium of the Botanic Gardens, Singapore.

TABULATED STATEMENT OF THE QUEENSLAND SPECIES.[8]

Tribus II.—Tecomeæ.

* *Tecomaria* Fenzl.
  * 1. *capensis* (Thunb.) Fenzl.
Pandorea (Endl.) Spach.
  1. *pandorana* (Andr.) V. St.

Tecomanthe Baill.
  1. *Hillii* (F.v.M.) V. St.
Haussmannianthes V. St.
  1. *jucunda* (F.v.M.) V. St.
Dolichandrone (Fenzl.) Seem.
  1. *alternifolia* Seem.

Pandorea (Endl.) Spach.
  2. *Baileyana* (Maid. et Bak.) V. St.
  3. *jasminoides* (Lindl.) K. Sch.
  4. *leptophylla* (Bl.) Boerl.

Dolichandrone (Fenzl.) Seem.
  2. *filiformis* F.v.M.
  3. *heterophylla* F.v.M.
Deplanchea Vieill.
  1. *hirsuta* (Bail.) V. St.
  2. *tetraphylla* (R.Br.) F.v.M.

KEY TO THE GENERA.

1. Lianes .. .. 2.
   Trees, shrubs, or rambling shrubs .. .. 4.

2. Corolla valvate in bud. Leaves 3-foliolate .. .. 4. *Haussmannianthes.*
   Corolla imbricate in bud. Leaves pinnate, the upper ones often 3-foliolate .. .. 3.

3 Corolla large, 6½ cm. long. Calyx large, 2½ cm. long, campanulate, distinctly 5-lobed. Flowers in racemes .. 3. *Tecomanthe.*
   Corolla small, 1-2½ cm. long, rarely longer. Calyx small up to 6 mm. long, truncate or obscurely 5-toothed. Flowers in thyrses, rarely in racemes .. .. .. 2. *Pandorea.*

[8] Genera and species only observed in cultivation have been marked with *.

4. Leaves simple, large, verticillate, the upper ones rarely opposite, with large cup-shaped glands on the upper side on the base of the midrib. Flowers yellow .. .. 6. *Deplanchea.*

Leaves simple or pinnate, if simple rather small, always eglandular, scattered, opposite or sub-verticillate. Flowers white or scarlet .. .. 5.

5. Flowers white. Calyx spathaceous. Leaves and leaflets entire .. .. 5. *Dolichandrone.*

Flowers red. Calyx campanulate, 5-toothed. Leaflets serrate towards the apex .. .. 1. *Tecomaria.*

1. TECOMARIA.

Spach., Hist. Vég. Phan. 9 (1840) 137 ; Baill., Hist. Pl. 10 (1891) 41 ; K. Sch. in Engl. & Pr. Nat. Pfl. Fam. iv., 3b (1894) 230 ; Bur. & K. Sch. in Martius Fl. Bras. viii., pars 2 (1896-97) 307 ; Sprague in Dyer Fl. cap. iv., 2 (1904) 448 ; in Dyer Fl. Trop. Afr. iv., 2 (1906) 513 ; non *Tecomaria* Bur., Mon. (1864) 47 (*quæ est Stenolobium* D. Don).

Erect or scandent shrubs, with imparipinnate leaves and dense terminal racemes of orange or scarlet flowers. Calyx regular, campanulate, 5-toothed. Corolla-tube narrowly funnel-shaped or almost cylindric, curved, limb markedly bilabiate. Stamens 4, exserted, anther-lobes connate for the upper third part, divergent below. Disk cupular. Ovary bilocular, ovules 4-seriate in each cell. Capsule oblong-linear, much compressed parallel to the septum.

Species 3, all African.

1. **Tecomaria capensis** (Thunb.) Spach., Hist. Nat. Vég. 9 (1840) 137.

Baill., Hist. Pl. 10 (1891) 41 ; K. Sch. in Engl. & Pr. Nat. Pfl. Fam. iv., 3b (1894) 229 ; K. Sch. & Bur. in Martius Fl. Bras. viii., pars 2 (1896-97) 307 ; Sprague in Dyer Fl. cap. iv., 2 (1904) 448 ; in Dyer Fl. Trop. Afr. iv., 2 (1906) 514 ; V. St. in Bull. Jard. Buit. sér. iii., 10 (1928) 193 ; *Bignonia capensis* Thunb. Prod. (1794-1800) 105 ; *Tecoma capensis* Lindl., Bot. Reg. (1838) t. 1117 ; DC. Prod. 9 (1845) 223 ; *Ducoudræa capensis* Bur. Mon. (1864) 49 ; *Tecomaria capensis* (Thunb.) Fenzl. ex V. St., Diss. (1927) 832.

A rambling shrub 2 m. or more high. Branches subterete, minutely pubescent above, glabrescent below. Leaves opposite, shortly petioled, 5-12 cm. long ; leaflets 5-9, rarely 3, shortly stalked, elliptic, orbicular or rhomboidal, more or less oblique at the base, 10-30 by 8-20 mm. ; terminal leaflet ovate, acuminate, 20-45 mm. long ; all crenate, sometimes mucronulate, glabrescent above, pilose in the axils of the nerves below (domatia). Common peduncle of the inflorescence 4-10 cm. long, usually overtopping the leaves, bearing a raceme of numerous 3-florous cymes ; rhachis, pedicels, and calyx finely pubescent ; bracts linear-subulate, 4-6 mm. long, caducous. Calyx tubular-campanulate, strongly ribbed ; tube $3\frac{1}{2}$-5 mm. long ; teeth deltoid, apiculate, about 1 mm. long, ciliate. Corolla orange-red or scarlet ; tube laterally compressed, $2\frac{1}{2}$-$3\frac{1}{2}$ cm. long, 2 mm. in diam. at the base, pilose inside for the lower third ; anther-lobes 3 mm. long, $\frac{1}{2}$ mm. broad, divergent below. Stamens exserted, didynamous with a fifth rudimentary one, inserted at the middle of the tube. Capsule linear, flat, $7\frac{1}{2}$-$12\frac{1}{2}$ cm. long, 8-10 mm. broad, seeds narrowly winged.

Queensland : Enoggera Creek, near Brisbane, C. T. White in H.Br., fl. iii., 1916, escaped from gardens ; occurring in large patches here and there along the creek.

2. PANDOREA.

Spach., Hist. Vég. 9 (1840) 136 ; Endl. Gen. Pl. (1836-40) 711, n. 4114a (sectio) ; Bur. in Bull. Soc. Bot. Fr. 9 (1862) 163 ; Mon. (1864) 49 ; Benth., Fl. Austr. 4 (1869) 537 ; Baill., Hist. Pl. 10 (1891) 40 ; K. Sch. in Engl. & Pr. Nat. Pfl. Fam. iv., 3b (1894) 230 ; Boerl., Handl. 2 (1899) 590 ; Bail., Queensl. Fl. 4 (1901) 1133 ; Diels in Engl. Jahrb. 57 (1922) 498 ; in Nova Guinea, 14 (1927) 294, 301 ; V. St., Diss. (1927) 294-301, fig. 3a, b, e, 4 (geogr. distr.), 5, 7, 16 (phylog. relat.) ; V. St. in Bull. Jard. Buit. sér. iii., 10 (1928) 194.

Small to large glabrous lianes. Leaves opposite, 1-pinnate, 2-11-jugate, rarely 3-foliolate at the ends of the flowering twigs, mostly 2-4-jugate ; leaflets small to large, suborbicular to linear, entire or dentate. Thyrses terminal, often foliate at the base, rarely on the stems, peduncle often with opposite or verticillate often connate scaly bracts at the base. Flowers small, 1-2½ cm. long, rarely 5-7½ cm. long. Calyx always small, truncate or shortly 5-dentate, campanulate or mostly cupular. Corolla with a lower narrow-cylindric part, inside bearded at the anterior portion or rarely glabrous ; tube infundibuliformous or subcampanulate in the upper part, straight or curved, unequally 5-lobed, bilabiate. Stamens 4, didynamous with a fifth rudimentary one ; filaments filiform, mostly curved, the anthers touching each other. Ovary oblong, bilocular with 2 placentas in each cell, each placenta with numerous ovules in many rows. Capsule elliptic-oblong or somewhat curved, acuminate at the tip and cuneate at the base ; valves equal or subequal, boat-shaped, smooth, coriaceous to firmly coriaceous ; seeds numerous, flat, thin-membranously winged.

Species 7, distributed from Ceram and Lombok, New Guinea and East Australia, to Tasmania, and New Caledonia.

1. Corolla large, hypocraterimorphous, 4-5 cm. long, outside papillose-pubescent, creamy or pale rose streaked with carmine in the throat. Calyx cupular-campanulate, truncate or obscurely 5-toothed, 6 mm. long .. .. 2. *P. jasminoides.*
   Corolla small, 1-2½ cm. long, tube campanulately enlarged from the lower cylindric part or tubular. Calyx up to 3 mm. long .. .. 2.

2. Corolla tubular, with 5 very short lobes, tube often curved, 1½ cm. long and 3 mm. in diam. Leaves 3-jugate, Leaflets large, elliptic-oblong or obovate, 12½ by 6 cm., coriaceous. Primary nerves in 6-7 pairs ; nerves and reticulations distinctly prominent .. .. 3. *P. Baileyana.*
   Corolla with a narrow tubular part and campanulately enlarged towards the throat, 1-2½ cm. long, 6-15 mm. broad. Leaves linear to suborbicular. Extremely variable species, but nerves and reticulations never distinctly prominent, even often lacking, and leaflets mostly much smaller .. .. 1. *P. pandorana.*

1. Pandorea pandorana (Andr.) V. St. in Bull. Jard. Buit. sér. iii., 10 (1928) 198.

Bignonia Pandorana Andr., Bot. Rep. (1801) t. 81 ; *Bignonia pandorea* Vent., Jard. Malm. (1803) t. 43 ; *Bignonia pandoræ* Sims in Bot. Mag. 21 (1805) 865 ; *Tecoma australis*

R. Br., Prod. (1810) 471, reprint 2 (1827) 327; DC. Prod. 9 (1845) 225; Benth., Fl. Austr. 4 (1869) 537; F.v.M., Syst. Cens. 1 (1882) 99, ed. ii., 1 (1889) 166; Bailey, Queensl. Fl. 4 (1901) 1134; Compr. Cat. (1909) 364; Maid. & Campb., Fl. Pl. Ferns N.S.W., n. 11; *Bignonia australis* Ait., Hort. Kew. ed. ii., 4 (1814) 34; *Bignonia meonantha* Link., Enum. Hort. Berol. 2 (1822) 230; *Tecoma diversifolia* G. Don, Syst. 4 (1838) 224; *Tecoma meonantha* G. Don, Syst. 4 (1838) 224; *Pandorea australis* Spach., Hist. Nat. Vég. 9 (1840) 136; K. Sch. in Engl. & Pr. Nat. Pfl. Fam. iv., 3b (1894) 230; Diels in Engl. Jahrb. 57 (1922) 498; V. St. in Nova Guinea 14 (1927) 302; Diss. (1927) 859, fig. 3e, 4 (10) (geogr. distr.), 16 (phylog. relat.); *Tecoma floribunda* Cunn. ex DC. Prod. 9 (1845) 225; *Tecoma Oxleyi* Cunn. ex DC. Prod. 9 (1845) 225; J. M. Black in Transact. Roy. Soc. South Austr., vol. 39, p. 836; White & Francis in Proc. Roy. Soc. Queensl. 37 (1926) 166; *Tecoma ceramensis* T. & B. in Nat. Tijdschr. Ned. Ind. 25 (1863) 412; Miq. Ann. 1 (1864) 197, t. 5; Scheffer in Ann. Jard. Buit. 1 (1876) 40; *Pandorea ceramica* (T. & B.) Baill., Hist. Pl. 10 (1891) 40; K. Sch. in Engl. & Pr. Nat. Pfl. Fam. iv., 3b (1894) 230; Boerl., Handl. 2 (1899) 600; V. St. in Nova Guinea 14 (1927) 302; Diss. (1927) 852, fig. 4 (6) (geogr. distr.), 16 (phylog. relat.); *Tecoma pandorana* Skeels in U.S. Dep. Agric. Bur. Pl. Ind. 62 (1913) 62; *Bignonia Poincillantha* Zipp. nomen in Herb. Lugd. Bat. ex V. St. Diss. (1927) 302; *Pandorea Poincillantha* V. St. in Nova Guinea 14 (1927) 302; Diss. (1927) 857, fig. 4 (9) (geogr. distr.), 16 (phylog. relat.), incl. var. *fragrans* V. St. l.c.; *Tecoma Latrobei* F.v.M. ex V. St. Diss. (1927) 859, nomen in Herb. Paris.

Small or large glabrous woody climber, 2-6 m. high (or more ?), with twining branchlets. Leaves extremely variable, 5-20 cm. long, 1-4-7-jugate; rhachis subangular to marginate or even slightly winged, especially towards the apex, leaflets mostly subsessile, except the longer petiolulate terminal one, from nearly orbicular (and then mostly 1-jugate) to linear (and then mostly 4-7-jugate), rounded, obtuse, acute or even cuspidate at the apex, papyraceous to subcoriaceous, entire or coarsely crenate, 2-8 cm. long, 2-40 mm. broad; mostly perforately glandular on the underside; side-nerves absent or 3-7, mostly indistinctly prominent, reticulations often obscure or absent. Thyrses glabrous or puberulous, dense- or lax-flowered, 7-20 cm. long, long or short peduncled, mostly leafy at the base, or only with reduced leaves, rarely nearly reduced to racemes (and then the leaflets mostly linear or linear-lanceolate). Flowers very variable in size, 1-2½ cm. long, on pedicels 5-10 mm. long. Calyx glabrous or puberulous, 2-3 mm. long, cupular, truncate or 5-toothed sometimes with distinct lobes, teeth broadly triangular, mostly ciliate. Corolla creamy or white, streaked with red in the throat and at the base of the lobes, often with red spots on the bases of the three anterior lobes, rarely yellow or yellowish with darker throat; tube infundibuliformous to campanulate, sometimes ventricose, glabrous outside, inside bearded on one side; limb zygomorphic, puberulous on both sides, anterior lobes bearded at their base. Stamens 4, didynamous, included; filaments curved, glandularly hairy at the base; anther-cells divaricate. Disk annular. Ovary sub-compressed, often glandular, 2-celled, each cell with 2 placentas, each placenta bearing numerous ovules in many rows. Capsule 3-7½ cm. long, oblong, acute or slightly acuminate at both ends, sometimes rostrate at the apex, straight or somewhat curved; valves firmly coriaceous, boat-shaped; septum thickened; seeds flat, oblong or rounded, surrounded by a transparent wing.

Distribution from Lombok, Ceram, and New Guinea to East Australia and Tasmania.

Queensland : Rockingham Bay, Dallachy in H.L.B., H.P., H.U. ; Moreton Bay, F. v. Mueller in H.L.B. sub. n. 900.81-135, H.P., H.U. ; Australia Felix, F. v. Mueller in H.L.B., H.P., H.U. ; Burdekin River, F. v. Mueller in H.P. ; same locality, ex Herb. Beaudoin in H.P. ; same locality, Banks and Solander in H.P. ; Herberton, J. F. Bailey (F. M. Bailey, l.c.) ; Neerkol Creek, Bowman in H.B. ; cultivated in Brisbane Garden, Mn. in H.Br. ; without locality, Mrs. Helms in H.Br. ; Jale River, R. C. Burton in H.Br. ; S. W. Dodd (Kga. Nursery), F. M. Bailey in H.Br. ; Eidsvold, T. L. Bancroft in H.Br. ; Mt. Lookout, Suttor River, Miss F. Clemenson in H.Br. ; Stanthorpe, H. Wight in H.Br. ; same locality, T. Davidson in H.Br. ; Cape York, E. W. Bick in H.Br. ; Moreton Bay, without coll. in H.B. ; Bunya Mountains, C. T. White in H.Br. ; Blackall Range, C. T. White in H.Br. ; Innisfail, N. Michael 44 in H.B. ; Kilcoy, C. England in H.Br. ; Bowen, N. Michael in H.Br. ; Eungella Range *via* Mackay, W. D. Francis in H.Br. ; Yarraman, M. A. Cameron in H.Br.; Sinai, Oakview, F. Reynolds 27, 28 in H.Br. ; Russell Island, Miss E. N. Parker in H. Br. ; Townsville, N. Michael 490 in H.Br., 352 in H.B. ; Tiger Scrub, Orallo, Dunlop in H.Br. ; Mt. Perry, J. Keys 570 in H.Br. ; Bundaberg, without coll. in H.Br. ; Crow's Nest, F. H. Kenny in H.Br. ; Walsh River, T. Barclay Miller in H.Br. ; Wellington Point, J. Wedd 168 in H.Br. ; Brisbane River, F. M. Bailey in H.Br. ; Herberton, N. Michael in H.Br., J. F. Bailey in H.Br. ; Paroo-Bulloo watershed, near Adavale, W. MacGillivray in H.Br. ; Port Denison, Fitzalan 898 in H.L.B. 200-63, 200-65.

New South Wales : Port Jackson near Sydney in H.L.B. sub. n. 898.200-68 ; Blue Mountains near Sydney, in H.P. ; Wingham, J. L. Boorman in H.L.B. sub. n. 910.151-539 ; Paterson River, J. L. Boorman in H.L.B. sub. n. 908.146-2205 ; Australia Felix, F. v. Mueller in H.U. ; Port Jackson, Lhotsky in H.P. ; near Sydney, Arnony 44 in H.P. ; same locality, R. Brown in H.P. ; New South Wales, M. Busseuil in H.P. ; Sydney, M. Verreaux 53 in H.P. ; Port Jackson, Beaudoin 68 in H.P. ; without locality, A. Cunningham 386 in H.U. ; Coolabah, J. L. Boorman in H.L.B., Maiden and Boorman in H.P. ; New England district, Miss F. B. May in H.Br. ; Taronga near Sydney, Docters van Leeuwen 7255 in H.B. ; Bantry and Manly, J. H. Forrest in H.Br. ; Byron Bay, J. L. Boorman in H.Br. ; Manly, J. H. Forest in H.Br. ; Cowra, R. Gemell in H.Br. ; Genoa River, A. Mar and Tailor in H.L.B. sub. n. 898.200-96.

Victoria : Victoria, Duncan in H.P. ; without locality in H.L.B. sub. n. 898.200-61 ; Hume River, F. v. Mueller in H.S.

Tasmania : Without locality in H.P.

This species is exceedingly variable in all kinds of characters. The leaves vary from 1-jugate with large obtuse ovate leaflets to 5-7-jugate with linear ones with all desirable intergrades even on the same twig. The colour of the corolla is most times described as creamy and red streaked inside, being odorless, sweet-scented, or disagreeably smelling. The length of the corolla varies from 1 to 2·7 cm. the lobes included. The nervature is distinct in the broader and larger leaflets but is absent in the narrow-lanceolate and linear ones.

Notwithstanding these variable characters it does not seem possible to me to distinguish distinct varieties or subspecies, as all combinations of characters are present in the many specimens preserved in the Brisbane Herbarium. I saw the same thing in the Herbaria at Paris, Leyden, Utrecht, and Buitenzorg. I kept the forms or varieties of Bailey in my dissertation as subspecies, because I accept a variety in cases where a single hereditary character is present or absent. After having seen the rich material at Brisbane the distinction of subspecies also seems to me of no use here.

When cultivating the aberrant forms in Queensland it may certainly appear that some are constant, but in that case the number of these forms will be very great, and such a division can hardly be based on herbarium material. Moreover *P. australis* cannot be mistaken for the other Australian Tecomeæ, being quite sharply separated from them.

The most curious forms are those with linear leaflets without nerves and a more or less broadly winged leaf-rhachis. But even this form is connected to those with lanceolate leaflets by intermediate forms, e.g., by the specimens from Stanthorpe (H. Wright), and Russell Island (Miss E. N. Parker).

In a report on a collection of plants from the north-western region of South Australia made by Captain S. A. White, *Tecoma Oxleyi* was separated by J. M. Black from *T. australis* (Transact. Roy. Soc. South Austr., vol. 39, p. 836), in which he is followed by J. H. Maiden in his Census of New South Wales Plants. I think it not possible to distinguish specific characters, though it may be a conspicuous form if treated locally. Specimens with narrow leaflets (evidently from arid places, ? xerophytes) may have small or large flowers.

The leaves of youth-forms show a striking resemblance to those of *Pandorea leptophylla* (Bl.) Boerl, though there are fewer leaflets. *See* also note under "Excluded Species" at the end.

[2. **Pandorea Baileyana** (Maid. & Bak.) V. St., Diss. (1927) 849, fig. 4 (4) (geogr. distr.), 16 (phylog. relat.)

Tecoma Baileyana Maid. Bak. in Proc. Linn. Soc. N. S. Wales, ser. ii., 10 (1895) 592, pl. 51; Bail., Queensl. Fl. 4 (1901) 1134, Compr. Cat. (1909) 364, Fig. 1.

Tall woody glabrous climber. Leaves 1-pinnate, 3-4-jugate, sometimes exceeding 60 cm., mostly 15-25 cm. long. Branchlets 4 mm. in diameter. Petioles thickened at the base, 3-5½-7½ cm. long, subterete; leaf-scars connected by a prominent line; rhachis thickened near the insertions of the thickened bases of the petiolules; leaflets entire, nearly sessile, broad-oblong, acuminate, base oblique, rounded or slightly tapering, chartaceous or subcoriaceous; side-nerves 10-11, distinctly prominent on the underside as the reticulations, shining dark green above, dull pale green beneath. Inflorescence thyrsoid, paniculiformous, rather many-flowered, axillar, 7½-45 cm. long, mostly 15-20 cm.; peduncle terete, 2½ mm. in diam.; primary stalks 2-3 cm. long, 7-flowered on the average. Calyx articulate with a hypanthium, truncate, irregularly lobed or more or less distinctly 5-lobed, 3 by 4 mm., smooth, glabrous, purplish brown. Corolla tubular, incurved, 12-13 mm. long, shortly papillose-pubescent outside, cream-coloured ; lobes and throat shaded with pink tube inside somewhat bubbled, slightly hairy ; lobes almost equal, suborbicular, densely papillose-pubescent. Stamens 4, included, glabrous, anther cells ovate-oblong. Ovary sub-orbicular or ovate, style glabrous, exceeding the stamens, stigmatic lobes suborbicular crenate. Capsule unknown.

Fig. 1.—*Pandorea Baileyana.* Leaf and inflorescence (after Richmond River in H.Br.), x 5/12.

New South Wales : Mullumbimby Creek, Tweed River, W. Bauerlen (type) ; Richmond River, without coll. in H.Br. ; Mullumbimby, W. Bauerlen in H.Br., H.K.

This rare endemic Australian species is most nearly related to *P. stenantha* from New Guinea on account of its leaves and flowers. I have not observed verticillate leaves as mentioned by Maiden and Baker in their original description (copied by Bailey l.c.), but abnormal flowers sometimes occur.

Mr. C. T. White writes that though this species was recorded by Bailey l.c. as " near the Tweed River, W. Bauerlen" it has not yet actually been collected in Queensland territory, though possibly it grows there. Mr. Bauerlen's specimens were collected at Mullumbimby in New South Wales territory. As the species grows not very far from the Queensland border, and is further one of the only two Australian members of the family not found in Queensland, it is inserted here for the purpose of convenience.]

3. **Pandorea jasminoides** (Lindl.) K. Sch. in Engl. & Pr. Nat, Pfl. Fam. iv., 3b (1894) 230.

V. St. in Nova Guinea, 14 (1927) 302 ; Diss. (1927) 847, fig. 4 (3) (geogr. distr.), 16 (phylog. relat.) ; in Bull. Jard. Buit. sér. iii., 10 (1928) 195 ; *Tecoma jasminoides* Lindl. Bot. Reg. (1838) t. 2002 ; DC. Prod. 9 (1845) 225 ; Cunningham in Loud. Hort. Brit. p. 582 ; Don, Gard. Dict. 4 (1838) 225 ; Bot. Mag. t. 4004 ; Benth., Fl. Austr. 4 (1869) 537 ; F. v. Mueller, Syst. Cens. 1 (1882) 99, ed. ii., 1 (1889) 166 ; Bailey, Queensl. Fl. 4 (1901) 1134 ; Compr. Cat. (1909) 364.

Tall glabrous woody climber, ultimate branchlets terete, elenticellate. Leaves opposite, 1-pinnate, 2-3-(4)-jugate. Leaflets nearly sessile, the terminal one on a petiolule 10-15 mm. long, ovate to lanceolate, obtuse-acuminate, shining, entire, slightly concave at the base, $2\frac{1}{2}$-5 by 1-2 cm., or in ovate leaflets 3-5 by $1\frac{1}{2}$-$2\frac{1}{2}$ cm. ; nerves in 3-5 pairs, very indistinct ; reticulations none or minute, underside microscopically punctate. Thyrse terminal, subcorymbose, compact, 6 cm. long including the peduncle 3 cm. long. Flowers large, showy. Calyx glabrous, glandular, 6 by 5 mm., truncate or rarely obscurely 5-toothed ; teeth equal, broad-triangular, acute. Corolla infundibuliformous-campanulate, delicately milk-white and streaked with carmine in the throat, 4-5 cm. long, shortly papillose-pubescent outside ; tube 8-10 mm. broad, inside bearded near the insertions of the stamens at 5 mm. above the base ; limb flat, expanded ; lobes 5, rounded, somewhat wavy and crenate, very broad, half as long as the tube, pubescent inside ; throat scarcely bearded or marked inside with 2 decurrent lines, short hairs. Stamens 4, a fifth rudimentary one, included ; filaments glabrous. Disk annular-cupuliformous. Ovary 2-celled, each cell with two indistinctly separated placentas ; ovules numerous in many series on each placenta ; stigma bilamellate. Capsule oblong, mostly elliptic, acute or slightly acuminate at both ends, smooth, 5-10 cm. long ; valves thickly coriaceous, boat-shaped ; seeds flat, obcordate, with broad transparent wings.

Queensland : Moreton Bay, Cunningham (Bailey l.c.), C. T. White in H.Br. ; Brisbane River, F. v. Mueller (in lit.), F. M. Bailey in H.Br. ; Burdekin River, F. v. Mueller (l.c.) ; Ipswich, Nernst (Bailey l.c.) ; Brookfield, F. M. Bailey in H.Br. ; Eumundi, F. M. Bailey in H.Br. ; Rosewood, C. T. White in H.Br. ; Taylor's Range near Brisbane, C. T. White in H.Br. ; Bunya Mountains, C. T. White in H.Br. ; Eungella Range *via* Mackay, W. D. Francis in H.Br. ; Fraser Island, F. C. Epps in H.Br. ; Blackall Range, C. J. Gwyther in H.Br.

New South Wales : Richmond River, Henderson (Bailey l.c.) ; Clarence River, Beckler ? (Benth. l.c.).

This beautiful climber differs distinctly from the other Pandoreas by its large corolla and smooth leaves. It is often cultivated in the tropical regions and is used as a greenhouse plant in the temperate ones.

3. TECOMANTHE.

Baill., Hist. Pl. 10 (1891) 41 ; K. Sch. in Engl. & Pr. Nat. Pfl. Fam. iv., 3b (1894) 230 ; Boerl., Handl. 2 (1901) 590 ; Diels in Engl. Jahrb. 57 (1922) 496 ; V. St. in Nova Guinea 14 (1927) 294 ; Diss. (1927) 864 ; in Bull. Jard. Buit. sér. iii., 10 (1928) 201.

Tall rarely low climbers ; stem woody, sometimes with pendent roots inserted near the leaf-scars, but apparently not climbing by them. Leaves opposite, 1-5-jugate ; leaf-scars connected by a prominent line ; leaflets opposite, sessile or shortly petiolulate, the terminal one mostly longer petiolulate, papyraceous to coriaceous, mostly totally glabrous, entire or dentate in the upper half. Flowers in axillar racemes, rarely in axillar thyrses (*T. montana* and *T. saxosa*), solitary or rarely 2 or 3 in the axils of the leaves or mostly on the old wood in the axils of leaf-scars, mostly shorter than 5 cm., seldom longer ; peduncle at the ultimate base with scale-like bracts, rarely with reduced leaves ; pedicels with a bract and 2 bracteoles. Calyx campanulate, rarely suburceolate, large, mostly 2½-4 cm. long, with 5 eglandular large lobes, rarely smaller (*T. montana*) or subtruncate (*T. aurantiaca*). Corolla large, 5-10 cm. long, rarely smaller (*T. montana*), straight or curved, glabrous or puberulous at the apex, red, reddish, or rarely orange ; tube below with a narrow inside pubescent part, infundibuliformous enlarged above, 5-lobed ; lobes large, mostly distinct enequal. Stamens 4, didynamous, with a fifth rudimentary one. Disk annular. Ovary 2-locular, each cell having 2 placentas on the dissepiment or the placentas are inserted in the corners of wall and septum ; ovules in many rows on each placenta. Capsule bilocular with 2 coriaceous boat-shaped valves ; seeds unknown.

Distributed from Ternate to Queensland ; species 16.

In Queensland only one species—1. *T. Hillii.*

1. Tecomanthe Hillii (F.v.M.) V. St., Diss. (1927), 894.

Tecoma Hillii F.v.M., Fragm. 10 (1877) 101 ; Bailey, Queensl. Fl. 4 (1901) 1133 ; Compr. Cat. (1909) 364 ; C. T. White in Queensland Naturalist, vol. 4 (1920) 99-101, with figure showing flowers and fruit.

Tall glabrous climber, 3 m. high with a similar diameter. Leaves 1-pinnate ; leaflets 5, oblong-lanceolate, 2·5-7·5 cm. long, rather thin, oblique at the base. Flowers abundant ; racemes 6-flowered. Calyx 12½-25 mm. long, membranous. Corolla 5-7½ cm. long, limb rosy purplish, tube pale, marked with purplish lines, lobes 6-8 mm. long, pubescent towards the margins. Stamens 4, didynamous ; filaments filiform, anthers yellow, cells equal, 3-4 mm. long, widely divergent ; staminodium 4-6 mm. long. Ovary compressed, style filiform, glabrous, stigmatic lobes sublanceolate. Capsule 3·75 cm. long.

R.S.—D.

Queensland: Fraser Island, W. R. Petrie in H.Br.; Hervey Bay, F. Turner in H.Br.

Cultivated in the Brisbane Gardens, F. M. Bailey in H.Br.

The only endemic and Australian species of this genus, allied to the New Guinean *T. venusta* and *T. cyclopensis.* The figured leaf is not quite of the normal type. The lowest leaflets are both divided into two unequal ones, one small lower-inserted one and the proper oblique one. Without doubt it is a true *Tecomanthe* on account of its raceme of large flowers. One of the flowers on the right shows a very peculiar aberrative structure. The calyx and corolla form a connate torted spatha with 10 gradually higher-inserted lobes, the upper portion being corolla-like.

Fig. 2.—*Tecomanthe Hillii.* (? Normal) leaf and inflorescence (after W. R. Petrie in H.Br.), x 4/7; transverse section of the ovary, magnified.

4. HAUSSMANNIANTHES.

Van Steenis, nom. nov.; *Haussmannia* F.v.M., Fragm. 4 (1864) 148; non Dunker (1846); Benth., Fl. Austr. 4 (1869) 539; Benth. & Hook., Gen. Pl. 2 (1876) 1041; F.v.M., Syst. Cens. 1 (1882) 99, ed. ii., 1 (1889) 167; Baill., Hist. Pl. 10 (1891) 21, note 2; K. Sch. in Engl. & Pr. Nat. Pfl. Fam. iv., 3b (1894) 223; Bailey in Bot. Bull. n. 13, Departm. Agric. Queensl. (1896) 11; Queensl. Fl. 4 (1901) 1136; Compr. Cat. (1909) 368, fig. 345; V. St., Diss. (1927) 901, fig. 5 s, t, 7 (2) (geogr. distr.), 16 (phylog. relat.); *Nyctocalos* (subgenus *Haussmannia*) Seem. in Journ. Bot. 8 (1870) 149.

High climber with opposite, 3-foliolate, pinnate leaves, without tendrils. Leaflets entire. Thyrses terminal or lateral, or terminal with reduced leaves at the base. Flowers pedicellate. Calyx campanulate, truncate or

5-toothed. Corolla tubular, bilabiate, 5-lobed ; lobes induplicate-valvate in bud. Stamens 4, didynamous, the fifth rudimentary, all of them exserted. Disk cupular, enclosing the ovary. Ovary bilocular with a transverse dissepiment ; ovules numerous, in several rows on 2 placentas ; style with 2 stigmatic lobes. Capsule oblong, opening by 2 concave valves as in *Pandorea* and *Tecomanthe*, acuminate ; seeds numerous, broad-membranously winged, septum broad, thick, perpendicular to the valves.

Monotypic genus. Endemic.

1. Haussmannianthes jucunda (F.v.M.) V. St., comb. nov.

Haussmannia jucunda F.v.M., Fragm. 4 (1869) 539 ; Bailey in Bot. Bull. n. 13, Departm. Agric. Queensl. (1896) 11 ; Queensl. Fl. 4 (1901) 1136 ; Compr. Cat. (1909) 368, fig. 345 ; V. St., Diss. (1927) 902, fig. 5 s, t.

Tall, glabrous, luxuriant climber, with terete branchlets. Lower leaves rarely 1-foliolate, shining on both sides with a rather long slightly striate petiole, 4-6 cm. long ; leaflets concave, subcoriaceous, articulate at the end of the petiole, ovate or oblong, narrowed into the petiolules, lateral ones 5-10 mm., terminal one 2½ cm. long, petiolulate ; terminal leaflet sometimes confluent with one of the lateral ones ; blade 9-11 by 4·5 cm. ; side-nerves 8-10, curved, patent, reticulately connected, prominent below, lax. Flowers rapidly dropping. Thyrses 5-15 cm. long, rather few-flowered ; cymes 6-20 mm. long, opposite, 2-5-flowered ; bracts small, lanceolate ; pedicels 4-6 mm. ; bracteoles minute or absent. Calyx 4-6 mm. long, glabrous, subcoriaceous ; lobes 5, equal, broad-triangular, 2 mm. long. Corolla pinkish purplish, incurved, tube 2-2½ cm. long (lob. excl.), slightly dilated above the calyx ; lobes broad-ovate, 5 mm. long, hairy inside, arranged in 2 lips. Filaments hairy at their insertions, inserted below the middle of the tube. exceeding the corolla 7-10 mm. ; anther-cells divergent or divaricate. Disk 2 mm. long. Ovary short, slightly compressed. Capsule 7½-15 by 3½ cm., acuminate at both ends, smooth ; valves sometimes with a nipple-shaped minute appendix near the top ; septum broad, thick and firmly attached to both valves or to one of them, seeds pyriform, wrinkled, broad-transparently winged ; wings 1 cm. broad.

Queensland : Thursday Island, E. Cowley (Bailey in lit.) ; Redlynch road near Cairns, E. Cowley in H.Br., common ; Atherton, F. M. Bailey in H.Br. ; Johnstone River, G. H. Ladbrook 65 in H.Br. ; Freshwater Creek, Cairns, L. J. Nugent (Bailey l.c.) ; Stony Creek, Cairns, L. J. Nugent (Bailey l.c.) ; Harvey's Creek and Mulgrave River, F. M. Bailey (Bellenden-Ker Exped.) in H.Br. ; Seaview Range, Rockingham Bay, Dallachy in H.L.B. sub. n. 898,199-71, H.P., type specimen ; Rockingham Bay, F. v. Mueller in H.L.B. sub. n. 898,199-70, H.P.

Cultivated in the Botanic Gardens at Brisbane, F. M. Bailey in H.Br.

This climber seems to be rather common in the scrub, but fruiting specimens have rarely been collected. Its relations are to be found among *Pandorea*, *Tecomanthe*, and especially in *Neosepicæa*, a New Guinean climber. All these genera show the same structure of the capsule. It is easily distinguished by the valvate corolla, the exserted stamens, and the cupular disk.

5. DOLICHANDRONE.

Seem. in Ann. Mag. Nat. Hist. ser. iii., 10 (1862) 31 ; in Journ. Bot. 1 (1863) 236, 8 (1870) 379 ; Benth. & Hook., Gen. Pl. 2 (1876) 1046 (sect. *Markhamia* et *Muenteria* excl.) ; Baill., Hist. Pl. 10 (1891) 48 ; K. Sch. in Engl. & Pr. Nat. Pfl. Fam. iv., 3b (1894) 240 ; Sprague in Kew Bull. (1919) 303 ; V. St., Diss. (1927) 928, fig. 3 1, 10, 11 (geogr. distr.) ; *Dolichandrone* (sectio) Fenzl in Denkschr. Baier. Bot. Ges. Regensb., 3 (1841) 113, 265 ; *Spathodea* R.Br., Prod. (1810) 471 ; Bur., Mon. (1864) 50, t. 27 ; non Beauv.

Trees with pinnate or simple, opposite, pseudo-verticillate or scattered leaves; leaflets elliptic to filiform, entire or denticulate. Flowers in terminal racemes or thyrses nocturnal, fragrant. Calyx spathaceous, almost arcuate. Corolla white ; the lower part of tube long funnel-shaped, much exceeding the calyx ; limb subequally 5-lobed, mostly crispate or dentate. Stamens 4, didynamous with a fifth rudimentary one inserted in the throat ; anthers glabrous, bilocular. Disk annular, cushion-shaped. Ovary sessile with numerous ovules in many rows. Capsule subcylindric or compressed-siliquiform, often spirally twisted, elongate, loculicidal, pseudo-quadrilocular owing to an incomplete false septum. Seeds in 4-6 rows in each cell, corky or membranously winged.

Species 9, from East Africa to S. E. Asia, North Australia, and New Caledonia. Type species : *D. spathacea* (L.F.) K. Sch. All species of the sub-genus Coriaceæ V. St. are endemic in Australia, of the Membranaceæ V. St. not a single species has been found there.

Coriaceæ V. St., Diss. (1927) 931.

Small scrubby glabrous trees. Leaves simple or 1-pinnate, scattered, opposite or verticillate ; leaflets coriaceous, mostly lanceolate or linear, with ± parallel equal-prominent primary, secondary, and tertiary nerves.

1. Leaves and leaflets filiform .. .. 1. *D. filiformis.*
   Leaves or leaflets broader .. .. 2.

2. Leaves simple, ovate, mostly scattered or irregularly opposite .. 2. *D. alternifolia.*
   Leaves simple or 1-3 jugate, lanceolate or linear, scattered, opposite or mostly in whorls of 3 .. .. 3. *D. heterophylla.*

[1. **Dolichandrone filiformis** F.v.M., Fragm. 4 (1864) 149, in obs.

Seem. in Journ. Bot. 8 (1870) 383 ; F.v.M., Syst. Cens. (1882) 99, ed. ii., 1 (1889) 167 ; Sprague in Kew Bull. (1919) 304 ; V. St., Diss. (1927) 931, fig. 10c, 11 (3) (geogr. distr.) ; *Stereospermum filiforme* DC. in Bibl. Univ. Gen. (1838) ; *Bignonia filiformis* A. Cunn. in Ann. Sc. Nat., sér. ii., 9 (1839) 286, nomen ; *Spathodea ? filiformis* DC. Prod. 9 (1845) 249 ; Benth., Fl. Austr. 4 (1869) 539 ; Ewart & Davies, Pl. North. Terr. p. 250 ; Bailey, Queensl. Fl. 4 (1901).

Small glabrous tree. Leaves irregularly 3-verticillate, irregularly opposite or scattered, pinnate, 1-3-jugate ; rhachis terete ; leaflets filiform, terete, 15-25 cm. long and distant or more crowded and shorter. Racemes terminal, few-flowered, 5-10 cm. long, shorter than in *D. heterophylla* ; pedicels elongate, 3-5 cm. long, longer than in *D. heterophylla.* Calyx glabrous, smooth, spathaceous, 1½-2 cm. long, arcuate. Corolla white, ca. 5 cm. long, glandular ; tube narrow ; lobes undulate-dentate. Ovary glabrous. Capsule subcylindric when dry, terete when fresh, arcuate, up to 25 cm. long, glabrous ; seeds as in *D. heterophylla*.

North Australia : Mt. Essington, Leichhardt in H.P. ; Victoria River, F. v. Mueller in H.P. ; Copeland Island, A. Cunningham in Herb. Cook (Seem. l.c.)

Not yet collected in Queensland, but recorded here for the purpose of convenience, as one of the only two non-Queensland members of the family.]

2. Dolichandrone alternifolia Seem. in Journ. Bot. 8 (1870) 340, 382.

Benth. & Hook., Gen. Pl. 2 (1876) 1046 ; Sprague in Kew Bull. (1919) 303 ; V. St., Diss. (1927) 934, fig. 10a, 3 f, 11 (1) (geogr. distr.) ; *Spathodea alternifolia* R.Br., Prod. (1810) 472 ; DC. Prod. 9 (1845) 209 ; Benth., Fl. Austr. 4 (1869) 539 ; Bailey, Class. Ind. Pl. Queensl. Fl. 4 (1901) 1135 ; Compr. Cat. (1909) 368 ; *Dolichandrone heterophylla* F.v.M., Fragm. 4 (1864) 149, partim ; *Dolichandrone Brunonis* F.v.M., nomen in Herb. Paris, ex V. St., Diss. (1927) 935.

Small tree. Branchlets terete, smooth. Leaves scattered, alternate or irregularly opposite, coriaceous, entire, ovate or broadly ovate-lanceolate, at the base narrowed into the long petiole, obtuse or acuminate, sometimes emarginate up to 8-9 by 4-5 cm. ; veins oblique. Flowers unknown to me. Capsule arcuate, to 30 cm. long, flat, smooth, slightly acuminate ; seeds rather narrow, including the wings 3 cm. long ; germ 10 by 5 mm.

North Australia : Gulf of Carpentaria, without coll. in H.P.

Queensland : Endeavour River, Banks and Solander (Benth. l.c.) ; Burdekin River, F. v. Mueller (Benth. l.c.) ; Upper Lynd, Leichhardt in H.P. ; Rockingham Bay, Dallachy (Sprague l.c.) ; between Cleveland Bay and Rockingham Bay, Hill (Sprague l.c.) ; Thursday Island, Jaheri in H.B., fr. 19 v., 1901 ; without locality, T. Barclay Miller, 33 in H.Br., shrub or tree, runs 6-14 ft. high, all over the country, cattle and horses are very fond of it and break it down ; Gulf country, D 4, T. L. Bancroft in H.Br.

D. alternifolia is allied to *D. heterophylla* and has been considered as a mere variety of this species by various authors.

It is limited to the north-eastern part of Australia ; though it has been observed in Thursday Island it does not occur in New Guinea.

3. Dolichandrone heterophylla F.v.M., Fragm. 4 (1864) 149, in obs., excl. syn.

Seem., Journ. Bot. 8 (1870) 382 ; F.v.M., Syst. Cens. 1 (1882) 99 ; Sprague in Kew Bull. (1919) 304 ; V. St., Diss. (1927) 935, fig. 10b, 11 (2) (geogr. distr.) ; *Spathodea heterophylla* R.Br., Prod. (1810) 427 ; DC. Prod. 9 (1845) 207 ; Benth., Fl. Austr. 4 (1869) 538 ; Bailey, Queensl. Fl. 4 (1901) 1135 ; Ewart & Davies, Fl. North. Terr. p. 250 ; Bailey, Compr. Cat. (1909) 364, fig. 344.

Scrubby glabrous tree, 3-5 m. high, bark rugged. Leaves crowded in dense masses, mostly in whorls of 3, coriaceous, simple or pinnate, 1-3-jugate, rather varying, sometimes with 2 leaflets ; leaflets oblong-lanceolate to linear, 2½-7½ cm. long, simple leaves mostly lanceolate, 3½-12 cm. long, narrowed into the petiolule without articulation ; nerves and veins oblique, nearly parallel to the margin. Flowers white in few-flowered, short, terminal racemes 5-10 cm. long, fragrant ; pedicels 1-2½ cm. long. Calyx 2½ cm. long. Corolla-tube slender, 3½ cm. long, only dilated near the apex ; lobes nearly 6 mm. in diameter, broadly rounded ; margins undulate and crispate. Disk thick and fleshy. Capsule from 5 to more than 30 cm. long, compressed when dry ; valves slightly concave ; false septum almost reaching the margins of the valves ; seeds, including the 1 cm. broad wings, 3 by ½ cm.

North Australia : Islands of the Gulf of Carpentaria, R. Brown in H.Br., Henne (Benth. l.c.) ; Victoria River, F. v. Mueller (Benth. l.c.) ; Careening Bay, N.W. coast, A. Cunningham (Benth. l.c.) ; Roebuck Bay, N.W. coast, Marten (Benth. l.c.) ; Kings Ponds, in the interior, McDouall Stuart (Benth. l.c.).

Queensland : Stannary Hills, T. L. Bancroft, fr. fl. xii., 1908 in H.Br. ; Newcastle Range, A. H. Blackman fr. vii., 1906 in H.Br.

6. DEPLANCHEA Vieill.

Bull. Soc. Lin. Norm. 7 (1862) 11 ; F.v.M., Syst. Cens. 1 (1882) 99, ed. ii., 1 (1889) 167 ; V. St., Diss. (1927) 906, fig. 8, 9 (geogr. distr.) ; in Bull. Jard. Buit. sér. iii., 10 (1928) 218 ; *Diplanthera* Banks & Sol., ex R.Br. Prod. (1810) 448, reprint 1 (1827) 304 ; Endl., Gen. Pl. (1836-40) 676 ; DC. Prod. 8 (1845) 229 ; Bureau in Soc. Bot. Fr. 9 (1862) 16, Mon. (1864) 51 ; F.v.M., Fragm. 5 (1865) 72, 214 ; Seem. in Journ. Bot. 3 (1865) 93 ; F.v.M. in Journ. Bot. 5 (1867) 212 ; Benth., Fl. Austr. 4 (1869) 540 ; Scheffer in Nat. Tijdschr. Ned. Ind. 31 (1870) 332 ; Seem. in Journ. Bot. 8 (1870) 148, 163 ; Benth. & Hook., Gen. Pl. 2 (1876) 1048 ; Baill., Hist. Pl. 10 (1891) 44 ; K. Sch. in Engl. & Pr. Nat. Pfl. Fam. iv., 3b (1894) 235 ; Ridley, Fl. Mal. Pen. 2 (1923) 552 ; V. St. in Nova Guinea, 14 (1927) 293 ; Endert, Diss. (1928) 133 ; *Bulweria* F.v.M., Fragm. 4 (1864) 147 ; *Montravelia* Montr., nomen ex Beauvisage in Ann. Soc. Bot. Lyon 26 (1901) 89.

Trees with thick branches. Leaves large, verticillate (rarely opposite on young shoots), simple, ovate or oblong, mostly with large glands at the base above, entire, mostly yellow-tomentose as the ultimate branches and the inflorescences, sometimes glabrous. Thyrses terminal, large, mostly yellow-tomentose. Flowers rather large. Calyx campanulate, coriaceous, valvate in bud, 3-lobed (posterior lobe entire, lateral lobes 2-toothed) or with 5 subequal lobes, sometimes with glands, hairy or glabrous. Corolla yellow, tubular-ventricose, subbilabiate, 5-lobed, dilated towards the throat, lobes nearly round. Stamens 4, didynamous, distinctly exserted, rarely with a fifth rudimentary one ; anthers with distinctly divergent cells, reflexed in bud. Ovary subsessile, bilocular, with 2 placentas in each cell which are sometimes adnate ; ovules numerous, in many rows ; style exserted with a bilamellate stigma. Capsule 2-valvate, oblong or lanceolate with strongly coriaceous or even woody valves ; seeds numerous, with a broad, finely membranous wing.

Species 8, distributed from the Malay Peninsula to East Australia, New Guinea, and New Caledonia ; type species : *Deplanchea tetraphylla* (R.Br.) F.v.M.

1. Leaves 4-verticillate (or on the youngest shoots rarely opposite), obovate, mostly cuneate at the base ; underside with a thick dense yellow tomentum ; nerves 7-9 on each side of the midrib. Rather tall tree .. .. .. 1. *D. tetraphylla*.

Leaves 3-verticillate (or ? rarely opposite), rather narrow lanceolate, more or less rounded at the base; underside hirsute, never with a dense tomentum; nerves 18-19 on each side of the midrib. Rather ? small tree .. 2. *D. hirsuta.*

1. **Deplanchea tetraphylla** (R.Br.) F.v.M., sens. ampl.

Syst. Cens. 1 (1889) 167; V. St., Diss. (1927) 916, fig. 8 c, d, j, 9 (2) (geogr. distr.); *Diplanthera tetraphylla* R.Br., Prod. (1810) 448, reprint (1827) 304; Verm. Bot. Schrift iii., 1 (1827) 305; Benth., Fl. Austr. 4 (1869) 540; Scheffer in Nat. Tijdschr. Ned. Ind. 31 (1870) 334; Ill. Bot. Cook's Voy., p. 72, t. 229; Bail., Queensl. Fl. 4 (1901) 1137; Compr. Cat. (1909) 368; White in Proc. Roy. Soc. Queensl. 34 (1922) 52; White & Francis in op. cit., 37, n. 15 (1927) 259; V. St. in Nova Guinea 14 (1927) 293; *Bulweria nobilissima* F.v.M., Fragm. 4 (1863-64) 147; *Tecomella Bulwerii* F.v.M., Fragm. 5 (1865-66) 72, 214, nomen.

Big tree, stem diameter often exceeding 1 m.; wood whitish, close-grained and firm; bark thick, soft and somewhat corky; the crown of the tree irregularly diffuse, often umbrella-shaped; branchlets ca. 1 cm. thick. Leaves short-petioled, subcoriaceous to coriaceous, crowded at the ends of the branchlets, 4-verticillate (rarely on young twigs opposite), ovate, obtuse, or elliptical-obovate, or oblong, cuneate at the base, rather abruptly contracted into the petiole though never cordate, glabrous above, slightly scabrous, or pubescent on the main nerves, on the underside covered with a thick soft yellow tomentum, often with a golden or bronze hue and consisting of single or clustered but scarcely stellate hairs, the elder ones 30-60 by 30 cm. or broader, mostly (those of flowering specimens) 15-23 by 8-14 cm.; midrib at the base as thick as the petiole, strongly prominent; basal part above with 0-7, mostly 2-3 large brown cup-shaped glands; primary nerves 7-9, erect-patent, all making a sharp angle with the midrib, prominent as the wide reticulations; all nerves sunken in above; petiole stout, 3-5 by 0·25-0·4 cm., thickened at the base and spanning round one-fourth of the girth of the branch, yellow-tomentose; leaf-scars cordate, 6-7 mm. broad. Thyrses a dense layer of corymbose nature, terminal on the branchlets, 15-20 cm. in diameter, yellow-tomentose, sometimes nearly glabrous; peduncle stout, 9-12 by 0·8 cm. or much shorter, the upper half densely branched, often with some reduced leaves at the base; primary axis horizontal, whorled, terete, 4-6 cm. long, 2-3 times forked with a flower in each fork, sometimes 3-florous; bracts linear, 5-8 mm. long; pedicels of the lateral flowers $1\frac{1}{2}$-2 cm., those of the terminal ones 1 cm. long. Calyx coriaceous, 13 mm. long, articulate on a short hypanthium, broadly campanulate, yellow-pubescent when young; tube 7 by 8 mm. at the throat, 3-lobed, the posterior lobe recurved, the lateral ones erect split down to 3-4 mm. from the tip, all 10 by 9 mm., ovate-triangular, acute, somewhat carinate and indistinctly penicillate at the tip. Corolla yellow; tube campanulate, slightly exceeding the calyx, curved; limb bilabiate, $2\frac{1}{2}$ cm. long (lob. incl.), glabrous outside, 5-lobed; lobes as long as the tube, ovate-orbicular, margin ciliate. Stamens and style exceeding the corolla-tube by $2\frac{1}{2}$ cm. or more, divergent and curved towards the peduncle as the style. Stamens didynamous, inserted near the base of the corolla; filaments $3\frac{1}{2}$ and 4 cm. long, slightly pilose near the base; anthers with divaricate cells, reflexed in bud. Disk fleshy, flat. Ovary oblong, 4 mm. long; ovules in 5-6 rows on 2 distinct placentas in each cell. Capsule 5-7½ cm. long with woody, hard valves which are smooth inside with a longitudinal line where the thick somewhat fleshy dissepiment was attached; seeds flat, broad, but exceedingly fine-membranously winged.

Distribution : New Guinea and Queensland.

Queensland : Boar Pocket, J. F. Bailey in H.Br., fl. 16 vi., 1899, without locality in H.Br. ; Thursday Island, F. M. Bailey 85 in H.Br., fol. vi., 1897, Jaheri in H.B., fl. 19, v., 1901 ; Cairns, C. T. White in H.Br. ; Cardwell, F. M. Bailey in H.Br., J. L. Tardent in H.Br., fl. fr. xi., 1926 ; Temple Bay, Cape York Peninsula, J. E. Young in H.Br., fl. vii., 1923, tree with umbrella-shaped top up to 20 ft ; Cape York, MacGillivray, Daemel (Benth. l.c.) ; Musgrave Telegr. Station, Cape York Peninsula, T. Barclay Miller in H.Br. ; between Ingham and Townsville, N. A. R. Pollock in H.Br. ; Rockingham Bay, F. von Mueller in H.B., H.P., H.U. sub. n. 001067, 001066, Dallachy 1169 in H.S. ; Endeavour River, Banks and Solander (Benth. l.c.) ; Brisbane, off a plant cultivated at Bowen Park and brought from Cardwell, F.M. Bailey in H.Br.

2. Deplanchea hirsuta (Bail.) V. St., Diss. (1927) 920, fig. 9 (5) (geogr distr.).

Diplanthera hirsuta Bail. in Departm. Agric. Bot. Bull. 14 (1896) 11 ; Queensl. Fl. 4 (1901) 1137 ; Compr. Cat. (1909) 368.

? Small tree ; branchlets subterete and densely hirsute. Leaves in whorls of 3, rarely opposite on young shoots, acute to broadly truncate at the apex, up to 50 cm. in length with a breadth of 17 cm. about the centre ; margins repand, crenulate or deeply and very irregularly toothed ; base cordate and much undulate ; petiole 1½-4 cm., hirsute, later on nearly glabrous ; nerves rather irregular, not parallel, 18-19 on each side of the midrib, distinctly prominent as the gross and fine reticulations. Calyx 1¼ cm. long, campanulate, coriaceous, inside with scale-like glands, 3-lobed, 2 side-lobes emarginate. Corolla ringent, yellow, 2½ cm. long, spreading to 3¾ cm. wide ; lobes blunt, longer than the tube. Stamens 4, exceeding the corolla by 3·7 cm. ; style about the length of the stamens ; stigmatic lobes ovate-apiculate. Capsule unknown.

Queensland : Cairns, Stony Creek, L. J. Nugent in H.Br., a shoot and loose flowers ; Thursday Island, E. Cowley 56 in H.Br., large leaf (shoot cited by Bailey lost ?).

Notwithstanding the imperfect materials cited I am convinced that it is a distinct species, though it must be studied further, especially as to its distribution. The 3-lobed calyx and the short corolla-tube show its affinities with *D. tetraphylla*.

EXCLUDED SPECIES.

Pandorea leptophylla (Bl.) Boer.

This species is erroneously referred by me to the Queensland flora in Bull. Jard. Bot. Buit. sér. iii., 10 (1928) 201. The two specimens mentioned in that paper are youth-forms of *Pandorea pandorana*, as was found out by Mr. C. T. White from Queensland specimens, and by myself when studying the cultivated species in the Botanic Gardens at Buitenzorg.

LITERATURE CITED.

BAILEY, F. M.—Contribution to the Flora of New Guinea, in Queensl. Agric. Journ. Bot. 7 (1900) 349.

BAILEY, F. M.—The Queensland Flora 4 (1901) 1133-1137.

BAILEY, F. M.—Comprehensive Catalogue of Queensland Plants (1909) 364.

BAILEY, F. M.—Contributions to the Queensland Flora, in Bot. Bull. Departm. Agric. Queensl. 13 (1896) 1136, 14 (1896) 11.

BAILLON, H.—Histoire des Plantes 10 (1891) 1-58.

BENTHAM, C.—Flora Australiensis 4 (1869) 536-541.

BENTHAM, G., & HOOKER, J. D.—Genera Plantarum 2 (1875) 1026-1053.

BOERLAGE, J. G.—Handleiding tot de kennis der Flora van Nederlandsch Indie 2 (1899) 585-601.

BROWN, R.—Prodromus Flora Novæ Hollandiæ, etc., ed. i. (1810) 448, 470-472, reprint, (1827) 304, 326-328.

BUREAU, E.—Note sur les Bignoniacées de la Nouvelle Calédonie, in Bull, Soc. Bot. France 9 (1862) 162-165.

BUREAU, E.—Sur le genre Deplanchea Viell., in Bull, Soc. Linn. Norm. 7 (1863) 36.

BUREAU, E.—Monographie des Bignoniacées, Inaug. Diss., Paris (1864)

BUREAU, E., & K. SCHUMANN, Bignoniaceæ in Martius, Flora Brasiliensis viii., pars 2 (1896-97).

DE CANDOLLE, P.—Révision de la famille des Bignoniacées, in Bibl. Nat. Univ. Geneve 17 (1838). (Non vidi.)

DE CANDOLLE, P.—Bignoniaceæ, Prodromus 9 (1845) 142-248.

DIELS, L.—Die Bignoniaceæ Papuasiens, in Engl. Bot. Jahrb. 57 (1922) 498.

ENDLICHER, A.—Genera Plantarum (1836-40).

MAIDEN, J. H., & BAKER, R. T.—In Proc. Linn. Soc. N. S. Wales, ser. ii., 10, p. 592, t. 51. (Non vidi.)

MUELLER, F. VON.—Fragmenta Phytographiæ Australiæ 4 (1864) 149, 5 (1865) 21, 72, 214, 10 (1877) 101.

MUELLER, F. VON.—Note on Diplanthera, in Journ. Bot. 5 (1867) 212.

MUELLER, F. VON.—Systematic Census of Australian Plants 1 (1882) 77, ed. ii., 1 (1889) 167.

MUELLER, F. VON.—Descriptive Notes on Papuan Plants 9 (1890) 64.

PRESL, K. B.—Symbolæ Botanicæ, etc., 2 (1833) 28, t. 77. (Non vidi.)

PRESL, K. B.—Botanische Bemerkungen (1845), reprint from Abh. Böhm, Ges. Wiss. 3 (1845) 523. (Non vidi.)

SCHEFFER, R. H. C. C.—Het geslacht Diplanthera Banks & Sol., in Natuurk. Tijdschr. Nederl. Indie 31 (332-336).

SCHUMANN, K.—Bignoniaceæ in Engler & Prantl, Die natürlichen Pflanzen familien iv., 3b (1894) 189-252.

SEEMANN, B.—Revision of the Natural Order Bignoniaceæ, in Journ. Bot. 1 (1863) 19-23, 87 ; 5 (1867) 373 ; 8 (1870) 145-149, 163, 210, 337-340, 370-382.

SPACH, E.—Histoire Naturelle des Végétaux 9 (1840) 128-140.

SPRAGUE, T. A.—Bignoniaceæ in Dyer, Flora Capensis 4, 2 (1904) 448.

SPRAGUE, T. A.—Bignoniaceæ in Dyer, Flora of Tropical Africa 4, 2 (1906) 512.

SPRAGUE, T. A.—Dolichandrone and Markhamia in Kew Bull. (1919) 302-314.

STEENIS, C. C. G. J. VAN.—Bignoniaceæ in Nova Guinea 14 (1927) 292-303.

STEENIS, C. C. G. J. VAN.—Malayan Bignoniaceæ, their taxonomy, origin, and geographical distribution in Rec. Trav. Bot. Néerl. 24 (1927) 787-1049, cited as Diss.

STEENIS, C. C. G. J. VAN.—The Bignoniaceæ of the Netherlands Indies, in Bull. Jard. Bot. Buitenzorg, sér. iii., 10 (1928) 173.

URBAN, I.—Ueber Ranken und Pollen der Bignoniaceæ, in Ber. Deutsch Bot. Ges. 34 (1916) 728-758.

VENTENAT, E. P.—Choix des Plantes, etc. (1803). (Non vidi.)

VENTENAT, E. P. Jardin de la Malmaison, etc. (1803-4). (Non vidi.)

VENTENAT, E. P.—Decas generum novorum, etc. (1808). (Non vidi.)

VIEILLARD, E.—Sur les genres Deplanchea et Oxera, in Bull. Soc. Linn. Norm. 7 (1862) 11.

WHITE, C. T.—Contributions to our knowledge of the Flora of Papua, in Proc. Roy. Soc. Queensl. 34 (1922) 52.

A rare and beautiful native Tecoma in "The Queensland Naturalist," iv. (1920) 99-102, with figures.

WHITE, C. T., & FRANCIS, W. D.—Contribution to the Queensland Flora No. 3, in Proc. Roy. Soc. Queensl. 37 (1926) 166.

WHITE, C. T., & FRANCIS, W. D.—Plants collected in Papua by C. E. Lane Poole, in Proc. Roy. Soc. Queensl. 37 (1927) 259.

Revisional Notes on the Tribe Brachyrrhopalini (Robber Flies), with Remarks on Habits and Mimicry.

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(*Read before the Royal Society of Queensland, 24th June, 1929.*)

The genus *Brachyrrhopala* was proposed for a single species in 1847, namely *B. ruficornis* Macquart, the leading diagnosis being the short clubbed character of the abdomen, this narrowing to the apex of the second segment, widening from there and being rounded at the apex of the abdomen.

Roder recognised the genus and widened it by placing thereunder other but unrelated forms with clubbed abdomen. He described *B. victoriæ* and *B. maculata,* also he placed *Dasypogon maculinervis* Macquart there.

Ricardo followed Roder's arrangement, describing *B. fulvus,* but suggested *Codula quadricinctus* Bigot was identical. She also included *Codula fenestrata* Macquart, referring *B. victoriæ* as a synonym of it. In addition she placed *Dasypogon limbipennis* Macquart under the genus, but erroneously regarded *Dasypogon maculinervis* Macquart as a synonym of it. She further confused the genus by including *Dasypogon nitidus* Macquart.

White subsequently followed Ricardo, adding *Brachyrrhopala bella.* Up to this time the only criticism of the position was given by White:—"*B. fenestrata* differs so much from *B. nitidus* and *B. limbipennis* in the shape of the abdomen and much shorter wings that it might well be made the type of a new genus. It seems to be nearly allied to the genus *Codula,* but differs in having a curved terminal spine on the anterior tibiæ; this character, however, in some specimens is difficult to make out, and I am somewhat doubtful of its value as a generic character" (White 1916, p. 158).

White did not recognise the typical form of *Brachyrrhopala,* and had he done so he most certainly would have reversed his suggestion so as to place *B. nitidus* and *B. limbipennis* elsewhere. White's implied suggestion that *Codula* and *Brachyrrhopala* should be treated as one genus has also been suggested to me from another source, and it is one that I think would commend itself to many Dipterists, only there are augmentary characters subsequently given for the former genus that would prohibit this arrangement.

In the meanwhile *Codula limbipennis* remained uncertainly recognised, but its identity is now fairly well assured, so relationship between these genera can be cleared up as well as the identity of the species described under them. The disposition of species hitherto placd under these genera is as follows:—

Codula limbipennis Macquart is the genotype of *Codula* by original designation.

Codula vespiformis Thomson is a synonym of *C. limbipennis.*

Brachyrrhopala ruficornis Macquart is the genotype of *Brachyrrhopala* by original designation.

Codula fenestrata Macquart belongs to *Brachyrrhopala.*

Brachyrrhopala victoriæ Roder is regarded as a synonym of *B. fenestrata.*

Codula quadricinctus Bigot is a *Brachyrrhopala.*

Brachyrrhopala fulva Ricardo is a synonym of *B. quadricinctus.*

Recently I added *Cabasa* Walker as a synonym of *Brachyrrhopala,* thus bringing in four further specific names representing one valid species *Dasypogon pulchella* Macquart.

Dasypogon maculinervis Macquart is an *Erythropogon* White.

Dasypogon limbipennis Macquart is another *Erythropogon.*

Dasypogon nitidus Macquart is a *Neosaropogon.*

Brachyrrhopala bella White is near *Saropogon.*

Brachyrrhopala maculata Roder has not been recognised, but judging from the description is certainly not of that genus; compare with the descriptions of *Dasypogon sergius* and *D. fenestans* Walker, both placed by Ricardo in *Saropogon,* but more certainly belonging to *Neosaropogon.*

The genus *Cabasa* may be ranked as of subgeneric value on certain characters given in the key below. Other generic relationships in this tribe are clearly indicated in literature and need no special comment here.

Key to the Genera of the Brachyrrhopalini.

1. Thorax provided with a pair of lateral spines, one placed on each side immediately above the insertion of the wings. Moustache limited to the oral margin or practically so. Female with the ovipositor strongly compressed .. .. 2.

   Thorax without such spines, gibbous. Moustache usually extending above the oral margin, being represented there by soft hairs on the lower part of the face. Female with ovipositor not of the compressed type .. .. *Brachyrrhopala* 4.

2. Antennæ provided with four readily discernible segments and a minute apical spine .. .. .. *Chrysopogon* Roder.

   Antennæ with only three segments and a spine; at most the fourth segment is vestigial, the line of demarcation between it and the third being just visible .. .. 3.

3. Spine at apex of the third segment of antennæ large and conical. Abdomen with seven segments always visible. Tibial spur present .. .. .. *Opseostlengis* White.
Spine on third segment of antennæ minute. Abdomen with only six visible segments. Tibial spur absent. Thorax rather gibbous .. .. .. *Codula* Macquart.
4. Abdomen narrowest at the base of the second segment and always with eight visible segments. Moustache confined to the oral margin, or at most with a few hairs immediately above it. Black species with a highly gibbous bright-red thorax .. Subgenus *Cabasa* Walker.
Abdomen narrowest at the apex of the second segment. Face with many soft hairs extending well above the bristly ones on the oral margin. Thorax usually black and less gibbous .. Subgenus *Brachyrrhopala* Macquart.

Genus CODULA Macquart.

Macquart 1849, 70; Ricardo 1912, 149; Hardy 1921, 292.

This genus is sufficiently well diagnosed for recognition in the key given above, but it may be here added that the second segment of the abdomen is uniformly wide throughout and somewhat stouter than that in the genus *Brachyrrhopala*. I have not detected the seventh segment of the abdomen on the female when the ovipositor is exserted, and so suggest that this segment may ultimately be found reduced and absorbed by the very compressed ovipositor. Though resembling *Brachyrrhopala* in many respects, this genus shows in most of its characters that the affinities are nearer to *Chrysopogon*.

Codula limbipennis Macquart.

?Asilus conopsoides Fabricius 1775, p. 795; *?Dioctria conopsoides* Fabricius 1805, 151; Kertesz Cat. Dipt. 1909, 106 (which see for full references under these names).

Codula limbipennis Macquart 1849, 70, Pl. 7, fig. 1; Ricardo 1912, 149.

Codula vespiformis Thomson 1869, 464; Ricardo 1912, 150; Nicholson 1927, Pl. 1, fig. 3.

Synonymy.—Although there are many references to *Asilus* (*Dioctria*) *conopsoides* Fab., at most all are copies of the original description. None of the subsequent authors seem to have recognised the species, and Ricardo proposed to "expunge the name" as she considered it was impossible to ascertain the genus. The original description, however, fits the present species remarkably well, and the form is sufficiently *Conops*-like to be worthy of the name. It is certainly common enough to have been taken by Banks, and the only criticism I have to offer is that I have no record of its occurrence during the month when Banks visited these shores.

There can be little doubt concerning the remainder of the above synonymy and I have seen a sufficiently long series to be reasonably convinced that the various descriptions can apply to but one species, whilst Macquart's description and Ricardo's notes on the type conform to it.

Description.—The female has not hitherto been described; it conforms to the male in characters. The antennæ are not quite as in the *Brachyrrhopala*, for the fourth segment is still traceable, and they do not conform to those found in the genus *Chrysopogon.*

Habitat.—Queensland, New South Wales, and probably Victoria. The allotype female and a series of paratype females are in the Queensland Museum; other paratypes are in the collection of Mr. J. Mann.

Genus BRACHYRRHOPALA Macquart.

Macquart 1847, 36; Ricardo 1912, 486; White 1916, 156, and 1918, 74; Hardy 1921, 292, and 1926, 307, fig. 1.

Cabasa Walker 1850, 100; Ricardo 1912, 479; White 1916, 155; Hardy 1921, 291.

The genus *Cabasa* was previously placed as a synonym by me, and although some differences have since been discovered that would separate the form from *Brachyrrhopala*, these do not seem to be more than of subgeneric value. Three forms retained here as being of specific value may ultimately prove to be but one widely varying species, or two at the most. *B. ruficornis*, *B. fenestrata*, and *B. quadricincta* appear to be identical in structure, but there is another species as yet to be described that has the antennæ twice as long as on these, the legs are unicolorous and the wings lightly suffused with brown throughout. This undescribed form suggests that structures are not so consistent as hitherto thought to be, but that structures are not to be entirely relied upon as a criterion for species in this genus is seen by the new form here described. In this case we have a quite distinctive species that seems to conform to the *ruficornis* group in all its general structures. On this account I am leaving the status of the species in the *ruficornis* group unaltered, making the reservation that the status of two species is not quite satisfactory.

There is a new genus that is a member of the *Saropogonini*, but has a superficial appearance of the genus *Brachyrrhopala*. To this new genus I believe *B. bella* White comes. It is noteworthy in so far as a true moustache is not formed; instead it has long, soft, scattered hairs, disposed very much in the same way as the similar hairs of the thorax, none occurring on the oral margin. It is some years now since I last examined White's species and I made no detailed notes of that form at the time, but its description does not conform to the species before me.

Key to the species of the genus Brachyrrhopala.

1. A black species with a strongly gibbous red thorax, containing black markings. Wings varying from completely black to semi-hyaline. Abdomen varying slightly, either completely black, or metallic blue-black, or else with a white spot on the second segment; the sclerites are rather soft .. .. *pulchella* Macquart.

   Black, black and red, or black and yellow species, usually with some of the abdominal segments margined with red or yellow. Thorax never vivid red, at most obscurely red; less gibbous. Abdomen with hard rigid sclerites .. .. 2.

2. A black species with the dorsal area of the abdominal segments 4 to 6 completely reddish yellow (vivid red when alive). Wings almost completely brown. Antennæ, all knees, and posterior tarsi reddish yellow; the intermediate tibiæ may also be reddish .. .. *semirufa* n.sp.

Wings only partly suffused with brown, all legs partly red, abdomen banded with black and yellow or red .. .. .. 3.

3. Yellow on abdomen restricted to a narrow band at the apex of the second, third, and sixth segments. Wings infuscated across the base of the median cell, this marking runs to the base along the radial and cubital veins .. .. *ruficornis* Macquart.

Markings on abdomen not so limited .. .. 4.

4. Yellow on abdomen restricted to a band at the apex of the second, third, fifth, and sixth segments. Wings infuscated over most of the area, but leaving hyaline areas, conspicuously so in the basal and median cells. Face entirely black (or whitish at sides according to other authors) .. *fenestralis* Macquart.

Apex of most abdominal segments yellow, or this colour may extend over the whole of certain segments, and at least the second abdominal segment is mainly yellow. Wing markings vary from approaching that of *fenestralis* to that of *ruficornis*. Face yellow at sides .. .. .. *quadricinctus* Bigot.

Brachyrrhopala pulchella Macquart.

Dasypogon pulchella Macquart 1846, 62, Pl. 7, fig. 9.
Cabasa pulchella Hardy 1920, 185 (which see for synonymy and references).
Brachyrrhopala pulchella Hardy 1926, 307; 1927, 394; Nicholson 1927, Pl. 1, fig. 35.

There would appear to be one very variable species incorporated in the synonymy, and no published characters are found sufficient to distinguish lines of demarcation between these forms when long series are examined. A well-known but unpublished variation is described under a new name in the Gibbons manuscript and labelled in his collection; it has a white mark on the second segment of the abdomen. Even this character varies, the mark ranging from a small dot to occupying practically the whole of the dorsal area of the second segment; on old specimens this spot becomes obscure and difficult to detect. The species ranges from Tasmania to Queensland, but I have never seen a specimen from the former State having that white mark.

Brachyrrhopala ruficornis Macquart.

Macquart 1847, 36, Pl. 1, fig. 7; Walker 1854, 494; Roder 1883, 273; Ricardo 1912, 586; White 1916, 158; Hardy 1918, 66, and 1927, 394 (nec Froggatt 1907).

The female of this species was described from Tasmania, and the one specimen before me, a male, agrees remarkably well with the description. The sex was queried by Macquart, but it was undoubtedly given correctly as the male organs are always visible on specimens of this genus. The form was first rediscovered in the Littler collection in 1917, and the one before me is the only other specimen I have seen.

It differs from Tasmanian specimens of *fenestralis* chiefly in the wing marks, but also in the colour on the apical margin of the fifth abdominal segment. No intermediate forms have been seen from that State. Froggatt's record from Queensland is referable to *B. quadricinctus* Bigot, if indeed these forms are distinct.

Habitat.—Tasmania: Hobart, January, 1924, 1 male allotype.

Brachyrrhopala fenestrata Macquart.

Codula fenestrata Macquart 1849, 79, Pl. 7, fig. 2.
Brachyrrhopala fenestrata Ricardo 1912, 586; White 1916, 157.
Brachyrrhopala victoriæ Roder 1892, 241.

Originally described as from Tasmania, there is some doubt concerning the correctness of this type locality. My identification is based entirely on Tasmanian material, following White, but Ricardo recognised it from Victoria, and her redescription of the type certainly conforms to Tasmanian material more than to any known to me from the mainland. Many mainland specimens of Asilidæ, especially Queensland ones, are much lighter in colour than representatives of the same species from Tasmania, and Mr. H. Hacker, of the Queensland Museum, informs me he has noted similar lighter tones apply to certain Homoptera. Possibly in Victoria specimens are to be found that will complete the series of variations between the present species and *B. quadricinctus.*

Habitat.—Tasmania: Hobart, 24th January, 1915; Dunally, 21st February, 1918; Wynyard, February 1924. All three are females. The Wynyard specimen was one of several seen resting high up telegraph poles, and was difficult to catch.

Brachyrrhopala quadricincta Bigot.

?*Dasypogon nigrinus* Macquart 1849, 66; Ricardo 1912, 351.
Codula quadricincta Bigot 1878, 442; Ricardo 1912, 588.
Brachyrrhopala fulva Ricardo 1912, 588; Hardy 1927, 394.
Brachyrrhopala ruficornis Froggatt 1907, 300: (nec Macquart).
Brachyrrhopala fenestrata Nicholson 1927, text-fig. 3A and Pl. 1, fig. 24.

The type of *Dasypogon nigrinis* Macquart is a male in the Paris Museum, and it was examined by Ricardo, who states, "but the short antennæ seem to preclude it from belonging to the genus *Brachyrrhopala* or *Codula.*" Also she referred to the third segment of the antennæ as being "conical, about as long as the first two together." The length at least, as given by her in this manner, suggests *Brachyrrhopala* rather than otherwise. Fifth and sixth segments with testaceous margins, and the seventh testaceous, certainly conforms to the abdomen in this genus, as also other characters mentioned. The type locality is Tasmania, but as the description occurred in the fourth supplement probably Sydney is the true locality. I think the species may refer to the same as that known on the mainland as *B. fenestrata,* and not necessarily the same as that known under the name from Tasmania.

There can be little doubt concerning the correctness of the other references given above, part of which was suggested by Ricardo. The descriptions are referable to a very variable Queensland species that has the second abdominal segment entirely yellow or almost so. Even when very dark, and having the wing pattern similar to that of *B. fenestrata*, this is the case. The question now arises as to whether New South Wales and Victorian specimens named *fenestrata* in collections are not *quadricincta* Bigot, also it is pertinent to remark that if the colour of the second abdominal segment is not consistent, as it appears to be from a series of Queensland specimens, then there are no known characters to distinguish between *fenestrata* and *quadricincta* as here recognised. As far as I know them at present, geographical distribution, allied with colour characters, suggests that the two may hold good in their specific status.

Habitat.—Queensland: Brisbane and Stradbroke Island, September to February. New South Wales: Richmond River, October, 1 male.

Brachyrrhopala semirufa n. sp.

A very distinct species that can scarcely be confused with those referred to above. The head, thorax, anterior and intermediate femora except the knees, posterior femora except apex, the first two abdominal segments above and the whole area below, are all black. The remaining segments of the abdomen, when alive, are vivid red above, but on dried specimens fade to reddish yellow. The apices of all femora are reddish, as also the posterior tibiæ and tarsi. On one specimen the intermediate tibiæ are also reddish. As usual with species of this genus, the antennæ are reddish and the face is covered with yellow tomentum bordering the eyes, leaving a shining black central stripe. The wings are almost entirely suffused with brown, more anteriorly so along the veins; the membrane of the wing tends to become hyaline only near the posterior margin.

Length.—12 mm.

Habitat.—Queensland: Brisbane, the holotype, a male, September 1928; two paratype males, Brisbane and Stradbroke Island, December 1912. The two last are in the Queensland Museum and were taken by Mr. H. Hacker.

Genus CHRYSOPOGON Roder.

Roder 1881, 213; 1892, 234; Ricardo 1912, 481; White 1917, 72; Hardy 1921, 288; Malloch 1928, 300.

This genus would seem to come between *Opseostlengis* and *Codula* in regard to several of its characters. The spine at the apex of the antennæ is minute as in *Codula,* not large as in *Opseostlengis,* and the abdomen has seven visible segments as on *Opseostlengis,* whereas *Codula* has six. Most of the smaller forms have the abdomen widening from the base to the apex of the fourth segment; in *Opseostlengis* it widens to the apex of the fifth. However, one species, *C. mulleri,* narrows from the base to the apex of the second segment (which is a character of *Brachyrrhopala*), after which it widens out, but on the male of *C. mulleri* it becomes practically parallel from this point. It is not at all certain if the coalescence of M_1 and R_5 near the wing margin will be maintained entirely in the venation, but in the event of this failing the large size of the three species classed as having the character will readily group those forms. *C. crabroniformis* and *C. splendidissima* have been regarded by several entomologists as mimic forms of certain large wasps.

Key to the species of Chrysopogon.

1. Wings with M_1 and R_5 coalescing near the wing margin. Very large black and yellow species	2.
Wings with M_1 and R_5 separated at the wing margin. Abdomen widening from the base to the apex of the fourth segment. Medium and small sized species	4.
2. Abdomen narrowing from the base to the apex of the second segment, more or less widening from thence to the apex of the fourth segment. Moustache with one row of bristly hairs	*mulleri* Roder.
Abdomen widening from the base to the apex of the third segment. Moustache composed of one row of bristly hairs, rarely with hair above these	3.
3. Abdomen with segments 3 and 4 entirely black ..	*crabroniformis* Roder.
Abdomen with the third segment only partly marked with black, and the fourth above without black or almost so	*splendidissimus* Ricardo.
4. Moustache bushy along the oral margin. Abdomen with the first, base of second, third, and base of fourth segments black; elsewhere yellow	*albopunctatus* Macquart.
Moustache confined to one row of hair	5.
5. Abdomen banded with gold at the apex of the first to fifth segments, the base of the sixth also golden	*fasciatus* Ricardo.
Abdomen never with gold	6.
6. Abdomen entirely black, except some silvery lateral spots and narrow bands at incisions of segments may be present. Legs entirely black	*punctatus* Ricardo.
Abdomen never entirely black, or if so the legs are of a lighter colour	7.
7. Abdomen with a large part of the dorsal surface black, but laterally, the apex of the fifth, the whole of the following segments, and the whole abdominal area below is reddish brown	8.
Abdomen largely black, but usually from the second to sixth segments are reddish brown at apex; if the abdomen becomes entirely black, the reddish brown legs will distinguish the species	*queenslandi* Ricardo.
8. Legs reddish brown	*rufulus* White.
Legs entirely black	*nigricans* White.

Chrysopogon mulleri Roder.

Roder 1892, 243; Ricardo 1912, 483.

This species was described from Victoria, from which State specimens were seen by me some years ago. The specimens now before me were kindly lent by Mr. A. J. Nicholson, who took them in New South Wales; the male is from Capertee, and the female from Ilford, both dated 29th December, 1923. There is often a strong tendency for the abdomen to become greasy and the colour markings thus obscured.

Chrysopogon crabroniformis Roder.

Roder 1881, 213; Ricardo 1912, 483; Nicholson 1927, p. 47, Pl. ii., fig. 3.

This common Queensland species is apparently confined to inland districts. Those dated indicate the month of February is the time of their occurrence on the wing.

Chrysopogon splendidissimus Ricardo.

Ricardo 1912, 485.

Originally this was described as from Western Australia, so the form would appear to have a very wide range. Specimens before me are from Albury, New South Wales, 6-1-29 (F. E. Wilson), and Chinchilla, Queensland (A. P. Dodd), both being females.

Chrysopogon albopunctatus Macquart.

Dasypogon albopunctatus Macquart 1846, 193; Walker 1854, 578.

Laparus albopunctatus Schiner 1867, 369.

Neolaparus albopunctatus Kertesz 1909, 119.

Chrysopogon albopunctatus Ricardo 1912, 482; Dakin and Fordham 1922, 524.

Dasypogon spinther Walker 1849, 337; 1854, 478.

This was described by Macquart as from New South Wales, but it seems to be known only from Western Australia, where it is common and widely distributed. One specimen before me has a small species of *Apiocera* as prey.

Chrysopogon punctatus Ricardo.

Ricardo 1912, 484.

A pair in Mr. J. Mann's collection, captured in Brisbane during the months of December and January, are the only specimens I have seen. There is no mistaking this all-black form, which is not known outside Queensland. A female from Goondiwindi is allied, but has abundant hair above the moustache (December 1927, G. R. Bassingthwaighte).

Chrysopogon fasciatus Ricardo.

Ricardo 1912, 483; ??*Chrpsopogon sp.* near *fasciatus* Nicholson 1927, Pl. 1, fig. 21.

There are two species known to me that have the abdomen conspicuously marked with gold; in one the gold bands are interrupted; in the present case they are continuous across the abdomen. One female, Bunya Mountains, 3,000 ft., 9-1-26 (Dr. A. J. Turner).

Chrysopogon rufulus White.

White 1914, 268.

Five male specimens are before me, all from Perth, Western Australia; one of these is the type which White recorded as being a female, but he was misled by some foreign substance which adhered to the hypopygium and is now removed, showing the true nature of that organ.

Chrysopogon nigricans White.

White 1914, 268.

Two specimens, both females, are before me. White had access to these and the five *C. rufulus* referred to above, but he made no reference to other than the holotypes. The two forms are closely allied and the sexes are consistent in each case, thus suggesting they may be but the sexes of one dimorphic species, especially as all are from Perth, Western Australia.

Chrysopogon queenslandi Ricardo.

Ricardo 1912, 484.

There are two specimens in Mr. J. Mann's collection from Kuranda, December 1927 (A. P. Dodd), and a darker specimen in my own collection from Coen River (W. D. Dodd). Specimens originally described were also from Queensland, but Ricardo also reported a specimen from Western Australia which she considered to be the same species.

Chrysopogon pallidipennis White.

White 1918, 72.

The unique type was described from Sydney, New South Wales, and according to its published characters it would run out in the above key to *C. queenslandi.* White gives the colours as yellow, and there is a specimen before me from Southern Queensland that approximates White's description, this having yellow margins on the fifth and sixth abdominal segments, but the legs are coloured as in *C. queenslandi,* missing only the fuscous stains on the femora. It is possible that White described a pale specimen of *C. queenslandi,* and that the one before me is an intermediate variety. There is a still brighter form from Cairns, represented by five specimens in Mr. J. Mann's collection.

Chrysopogon rubripennis White.

White 1918, 73.

Not seen by me and was described from a unique Victorian specimen; it should be easily recognised by the claret-red thorax.

Genus OPSEOSTLENGIS White.

White 1914, 269; Hardy 1921, 288.

I have already given the generic characters of this genus, but attention must be drawn to the moustache which White states arises from the middle of the face; it is situated on the oral margin as in *Chrysopogon,* &c.

Opseostlengis insignis White.

White 1916, 269.

The unique type is a male, not female as White states; it is difficult to understand how this error arose, considering the claspers are clearly defined.

OBSERVATIONS OF SOME HABITS OF AND MIMICRY AMONGST ROBBER-FLIES.

These notes do not aim at crediting or discrediting any views expressed in favour of or against the theory of mimicry as far as it affects robber-flies. They reflect upon some aspects of the case that rather support the idea that mimicry may occur in the family in contradistinction to the views Melin (1923) expressed, which views uncompromisingly denounce the principles from several aspects. On reading Melin's remarks about robber-flies, one is rather strongly led to the view that these insects are robust and active enough to escape danger without having to resort to deceptive measures for their own protection. But this is not invariably the case, for I have caught many specimens, especially species of *Cerdistus,* by placing a tube over them whilst they were resting between their intermittent periods of hawking. A still weaker type is represented by species of *Leptogaster* which would appear to have very little protection against any insectivorous bird that might come their way, whilst the slow flight and the wary nature of their movements preclude them becoming seriously tangled in spiders' webs.

Where other invertebrates are concerned, robber-flies are the most skilled of their kind. I have not seen one preyed upon in Australia; on the other hand predaceans of most kinds succumb to them, including dragon-flies and spiders. Nor have I seen birds attempt to catch them, though I have watched birds pounce upon Bombyliidæ on the wing, these flies being more active in flight. Nevertheless there is one record of a bird eating a robber-fly, and several cases of insects, such as Mantis, bees, and wasps, that have gained the mastery when robber-flies have attacked them, these being noted in other countries. Many would seem to be caught in spiders' webs, but in Australia, although I have seen many arrested in this manner, they invariably break free again, if indeed they do not break right through in their headlong flight.

Nicholson (1927) has drawn attention to resemblances between certain robber-flies and wasps, but his work treats only with the principles of mimicry, and does not incorporate data of consequence to support the view that mimicry amongst robber-flies is indisputable.

There are, of course, varying degrees in mimicry, and no robber-fly seen by me in the field has had the perfection reached by certain Syrphidæ, especially *Cerioides subarmata,* which is well-nigh indistinguishable from a wasp in colouration, shape, and deportment, and moreover has advanced so far along this line as to fold its wings longitudinally as an Eumenid wasp, for which it is readily mistaken.

There would be no reason to doubt the occurrence of mimicry amongst robber-flies if such a case should be found where a mimic and its model were to be found to have identical colouration and deportment, so the question arises as to how far mimicry amongst robber-flies has gone, if at all.

A reasonable chance of attaining information is to ascertain if the mimic forms have adapted habits away from the normal of the family, tribe, or genus to which they belong, and if by so doing they have reasonably added to their chance of survival. It is to indicate possibilities along this line that the present note is written, and there is no intention to show here that mimicry is resorted to for the protective measures it may yield.

The genus *Leptogaster* is mainly found hunting and resting amongst grasses and reeds, not infrequently also around dead twigs on trees, especially in fairly dense bush where grassy undergrowth is not abundant. These flies rest on grass-stems and twigs alike, with their bodies held horizontally, and, when going into a state of coma, all their tarsi are bunched to grip their support immediately adjacent to the face. On twigs they invariably take up their position at the tip of the twig, becoming in this manner a continuation of the twig, having the appearance in this case of assuming a protective attitude of mimicry. On grasses and reeds no such state of mimicry can be expected, and, on the two or three times I have found them there in the state of coma, their colours did not particularly become absorbed by their surroundings.

The *Saropogonini* are all ground-frequenting at the time of oviposition. Many of them seem to be entirely ground-frequenting; in a few cases the male frequents flowers, rarely so the female, whilst in one case, *Erethropogon,* the species is abundant at flowers, and both sexes are to be taken in numbers there.

Erethropogon limbipennis is one of the mimic forms mentioned by Nicholson, and on account of its somewhat unusual habits is deserving of deeper study, both in structure and behaviour. So far, unlike the habits of other flower-frequenters, I have never seen the species with prey. Nicholson refers to its wasp-like nature as being not unlike *Polistes,* but from my own experience I have found in its general activities it resembles the Cerambycid beetle *Hesthesis ? cingulata* with which it occurs. One would never suspect any real resemblance by comparing specimens side by side, so the similarity depends entirely upon their actions. It is possible that these insects have a common model that was missing during my observations.

Two or three species of *Saropogon* also frequent flowers, and, like *Erythropogon limbipennis,* face the flowers, whereas *Thereutria* and other flower-frequenters seem to alight upon flowering shrubs and take up the attitude of awaiting prey, facing away from the flowers. *Sarapogon spp.* are not infrequently taken with prey, whilst *Thereutria* is a persistent hawker, taking restless intermittent flights.

Another species of this tribe was mentioned amongst mimics by Nicholson, namely *Neosaropogon princeps,* a rather large yellow and black form with a somewhat clubbed abdomen, more especially clubbed on the female. It seems to be entirely ground and low-shrub frequenting, and were it not for the fact that the abdomen is clubbed there would be no real resemblance to the Hymenoptera. In all probability the name covers a complex of species in collections, and therefore general remarks may not have any particular specific significance. I have had no difficulty in recognising its nature in the field; it was recognised as an Asilid because it acted like an Asilid, not like a wasp.

The *Phellini* apparently, and the *Laphrini* definitely, are mainly tree-frequenters; the *Atomosini* are ground-frequenting, and as far as I have met with them they are entirely confined to the bush, where *Cryptopogon* also occurs; the latter belongs to a tribe that is as yet unnamed, but another genus belonging to it, *Clinopogon,* contains a species that frequents sand-dunes on the coast, and its colour tones into its surroundings in a remarkably unnoticeable way, sharing in this feature the peculiarity of *Tabanus vetustus* Walker, *Platycarenum quinquevittata* Macquart, and certain other Diptera that also occur on coastal sand-dunes.

The *Brachyrrhopalini* have mixed habits, but owing to their general scarcity any definite information is not easy to acquire. *Codula* is said to frequent tree-trunks, and *Brachyrrhopala* is not uncommonly seen on shrubs, in one case on telegraph poles; one specimen in a state of coma was found on the upper side of a leaf of a persimmon tree, looking very like a Syrphid fly, nevertheless it was not wasp-like. In activity and habits they cannot be taken for anything but a robber-fly. The new species described above, *B. semirufa,* is superficially like the *Conops sp.* illustrated by Nicholson on Plate 1, fig. 9; the brightness of the red, when living, being as there given, thus bringing this species well within those types regarded as mimic forms. The genus *Chrysopogon* is recorded as ground-frequenting, but it is not certain if this habit is uniformly found throughout the genus. Nicholson remarks that *Chrysopogon crabroniformis* appears to have habits identical with *Neosaropogon princeps*; as the two species belong to different tribes, this observation may be very significant. Details of habits are wanted for the species, as several entomologists have drawn attention to its wasp-like nature in the field, and like *Erethropogon* it seems to have habits rather unusual for its type.

REFERENCES.

BIGOT.—1878: Ann. Ent. Soc. France, viii.

DAKIN & FORDHAM.—1922: Ann. Mag. Nat. Hist. (9) x.

FABRICIUS.—1775: Syst. Ent., p. 795. 1805: Syst. Antl., p. 151.

FROGGATT.—1907: Australian Insects.

HARDY.—1918: Proc. Roy. Soc. Tasmania for 1917. 1920, 1921, 1926: Proc. Lin. Soc. N. S. Wales, xlv., xlvi., li.

KERTESZ.—1909: Catalogas Dipterorum iv.

MACQUART.—1846, 1847, 1849: Dip. Exot. suppl. 1, 2, 4.

MALLOCH.—1928: Proc. Lin. Soc. N. S. Wales, liii.

MELIN.—1923: Zool, Bid. f. Uppsala, viii., pp. 301-8.

NICHOLSON.—1927: Austr. Zool., v., pp. 10-104.

RICARDO.—1912: Ann. Mag. Nat. Hist. (8), ix.

RODER.—1883: Wien Ent. Zeit., ii. 1892: Stett. Ent. Zeit., liii.

SCHINER.—1867: Verh. zool.-bot. Ges. Wien, xvii.

THOMSON.—1869: Eugenies Resa Dipt.

WALKER.—1849: List Dipt. B.M., ii. 1850: Ins. Saund. Dipt., i. 1854: List Dipt. B.M., vi., suppl. 2.

WHITE.—1914, 1916, 1918: Proc. Roy. Soc. Tasmania for 1913, 1916, 1917.

A Contribution to the Chemistry of the Oily Exudate of the Wood of *Pentaspadon motleyi.*

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(*Read before the Royal Society of Queensland, 24th June, 1929.*)

In 1924 Mr. C. E. Lane-Poole, Commonwealth Forest Officer, on his return from New Guinea brought a sample of the oily exudate from the wood of a tree, subsequently described by him in the publication "The Forest Resources of the Territories of Papua and New Guinea," p. 109, under the botanical name of "(near) *Pentaspadon motleyi.*"

The identification of the tree as *Pentaspadon motleyi* must be regarded as provisional only, owing to the difficulty experienced by Mr. Lane-Poole in obtaining complete specimens, the fruit being unprocurable. Mr. C. T. White, Government Botanist, in conjunction with Mr. W. D. Francis, who undertook the examination of the specimens, forwarded material to the Director of the Royal Botanic Gardens, Kew, England, for comparison with known specimens, the result being the provisional classification adopted.

Pentaspadon motleyi, with which the Papuan tree is thus provisionally identified, is indigenous to North Borneo, but the authors have been as yet unable to obtain authentic information regarding it. It is, however, hoped to obtain specimens from North Borneo for the purpose of investigation.

Pentaspadon officinalis is a better-known tree and its wood also exudes an oil. This tree is known to the Malay population of Perak as the source of "Minyak pelong," a dark-brown viscid oil which is held in great repute for skin diseases. This oil is stated by E. M. Holmes[1] to be of the consistency of liquid storax and to possess comparatively little odour. Efforts are being made to obtain a sample of this oil for examination.

Microscopic examination of the wood of *Pentaspadon motleyi* (Papua) was carried out by Mr. W. D. Francis in 1925, and the following report supplied to the authors:—

> "The vessels are single and scattered, or less frequently arranged in radial rows of 2–3; they measure ·15–·04 mm. in diameter and frequently contain tyloses. The wood fibres are septate and attain a diameter of ·02 mm. The rays are mostly heterogeneous and vary from ·5 to ·2 mm. in height and ·09–·015 mm. in breadth. The larger rays contain horizontal resin canals. Crystals are present in some of the cells of the rays.

[1] Journal and Transactions of the Pharmaceutical Society of London, vol. iii., p. 389.

The oil-like substance apparently exudes from the wood to a slight extent after it is dressed, as small patches of it appear on the planed longitudinal faces of the sample forwarded by Mr. Lane-Poole. The oil-like substance appeared in the sections of the wood as a brownish black deposit situated in the lumina of some of the fibres and in some of the cells of the rays. In transverse sections of the wood the brownish black deposit in the fibres was disposed in small patches consisting of 25 or fewer cells; sometimes it was seen in isolated fibres. In most cases the brownish black deposit dissolved in a solution of sodium hydroxide.''

At the request of Mr. Lane-Poole, we commenced a chemical examination of the exudate on receipt of samples, and a preliminary report submitted to him was published in the ''Forest Resources,'' p. 109.

The report may be quoted here:—

''The oil consists almost exclusively of acid substances, molecular weight about 400. These appear to be liquids of iodine absorption values of about 280. The acids form soaps with sodium hydroxide solution and are evidently of the nature of higher unsaturated acids. The oil does not contain any glyceride or esters and is somewhat of remarkable nature in being exclusively acid in character. Further investigation will be continued along the lines of isolation and identification of the individual acids (if more than one is present as seems likely).''

Subsequent to this preliminary examination a more detailed investigation was undertaken, but the supplies of oil available proved inadequate for complete and definite characterisation of the interesting acidic constituent of the oil. Efforts to obtain more oil had not been entirely abandoned when a paper[2] dealing with this same exudate appeared, the authors being A. R. Penfold and F. R. Morrison, Technological Museum, Sydney, who, at the request of Mr. Lane-Poole and with material supplied by him, examined the question of the economic importance of the exudate.

In view of this publication, and as our results do not confirm the molecular composition for the acidic constituent arrived at by these authors, it has been deemed advisable to publish our own conclusions as to its composition.

For the purpose of facilitating description we propose the name ''pentaspadonic acid'' for the principal constituent of the exudate, and as such it (with derivatives) will be referred to in this paper.

The exudate as submitted to us was almost black in colour, with a characteristic odour suggesting fish oil. Its acidic character was at once apparent by formation of metallic salts and almost complete soapy solution in aqueous sodium hydroxide. To the alcoholic solution ferric chloride imparted a violet colouration indicative of a phenolic group.

[2] Royal Society, N. S. Wales, vol. lxii., 218-224.

The following results of preliminary examination were recorded:—

$d_{15\cdot5}$ 1·007.

n^{20}_{D} 1·5284.

Acid number, 122.

Saponification number, 127.

Iodine value (Wijs ½ hour), 190.

Acetyl value, 130.

Ash left on ignition, ·15%.

Loss on heating in steam oven for two hours, 2–4%.

For separation of acidic or phenolic constituents from non-acid material, solution in dilute alcoholic sodium hydroxide solution was resorted to. The alcohol was expelled on the water bath, finally *in vacuo*, and the resulting dry soaps exhaustively extracted with boiling petroleum ether. (This method was found to give better results than the use of aqueous sodium hydroxide as a reagent, owing to the difficulties of extracting soapy solutions with ether.) In this way about 5 per cent. of the original exudate was extracted by the solvent and constituted non-acid material. Its small amount precluded examination, but it evidently contained a hydrocarbon which separated from alcoholic solution in crystals melting at 53° C. and appeared from combustion results to possess the molecular composition $C_{24}H_{50}$.

The residue of dry soaps from the petroleum ether extraction were dissolved in water and the solution acidified, resulting in the separation of a dark-brown oil similar to the original exudate.

For this purified acid material the following constants were observed:—

$d_{15\cdot5}$ 1·016.

n^{20}_{D} 1·5280.

Acid number, 137.

Acetyl value, 130.

Iodine value, 190.[3]

Combustion Results.—

Found C = 76·8 H = 9·5.

[$C_{23}H_{34}O_3$ requires C = 77·1 H = 9·6.]

Silver Salt.—The silver salt, prepared by adding silver nitrate to the neutral solution of the acid in alcohol, darkened rapidly on standing. A residue of 22% of silver was left on ignition.

Lead Salt.—The lead salt was precipitated from the neutral solution with lead acetate. It was almost insoluble in ether. Evidently a basic salt, it contained 36·2% of lead.

[3] Owing to it's phenolic group the iodine values of the free acid were probably in excess of the true value.

Barium Salt.—The barium salt, prepared by adding barium chloride to the neutral solution, contained 16 per cent. of barium.

Insoluble Bromides.—Insoluble bromides separated from acetic acid solution on adding a slight excess of bromine. The yield was 257 per cent. of the original acid. The percentage of bromine was determined as 46·2.

[$C_{23}H_{34}O_3Br_4$ requires 47·2%.]

Attempted Esterification of the Acid.—As the acid could not be distilled under diminished pressure without decomposition, attempts were made to esterify it in the usual way, but all attempts were unsuccessful, the original acid being recovered unchanged. We regard this inability of the acid to undergo esterification in the usual way as being due to steric hindrance, and of important significance with regard to its structure.

Methylation of the Acid.—The methyl ether of the methyl ester could, however, be readily prepared by using dimethyl sulphate and sodium hydroxide as methylating reagents, the phenolic group[4] undergoing methylation at the same time as the esterification of the carboxyl group. The methyl ether ester as so prepared proved to be very stable and distillable almost to the last drop, under diminished pressure, without decomposition, as a clear colourless liquid. It was accordingly distilled completely at 5 mms. pressure, for purposes of clarification and without any attempts at fractionation in order to record the constants of the complete sample, which were determined as follows:—

$d_{15\cdot5}$ ·9733.
n_D^{20} 1·5018.

Iodine value, 169.

Boiling point range, 240–245° C. at 5 mms. pressure.

No optical rotation was observed, pointing to the absence of asymmetric carbons.

Combustion Results.—

Found C = 78·4 H = 9·8.

[$C_{25}H_{38}O_3$ requires C = 77·8 H = 9·6.]

Methoxyl Determination.—A determination of methoxyl groups by Zeisel's method gave the following result:—

1·9562 grammes gave 2·19 grammes Ag.I.

This corresponds with two methoxyl groups, one of necessity present in the methyl ester group, the other as the methyl ether of the one phenolic group in the acid.

[4] The presence of one phenolic group was indicated by the acetyl value determined in preliminary analysis: the methoxyl group obtained on methylation remains unchanged in most of the substances described subsequently.

Fractionation of the Methyl Ester.—In order to determine the homogeneity or otherwise of the ester, fractional distillation at 5 mms. pressure was resorted to. The bulk of the oil boiled within a narrow temperature range 235–240° C. A small higher boiling fraction was, however, eliminated in this way, but the ester appeared undoubtedly to be largely one individual substance.

For the main fraction the following constants were determined:—

$d_{15 \cdot 5}$ .9754.

n_D^{20} 1·5108.

Iodine value, 130.

Combustion Results.—

Found C = 78% H = 9·7%.

Hydrolysis of the Methyl Ester.—It quickly became apparent that the methyl ester—we believe, owing to steric hindrance—was remarkably resistant to hydrolysis, thereby offering a parallel to the non-esterification of the acid by the usual methods and possibly accounting for the natural occurrence of the free acid. It was found necessary to heat the ester with concentrated alcoholic sodium hydroxide solution for at least ten hours to complete hydrolysis. The alkaline liquor so obtained was exhaustively extracted with ether before acidification. This served to eliminate a small amount of neutral material, possibly the methyl ether of a phenolic body (with no carboxyl group) which, we believe, is present in the exudate to a small extent.

On acidification of the alkaline liquor an oily acid separated, which in contrast to the original acid of the exudate could be readily distilled under diminished pressure (5 mms.) without decomposition.

The distilled acid—pentaspadonic acid methyl ether—was a pale-yellow liquid at ordinary temperatures, but solidified during a cold night or if placed in the refrigerator. The melting point was determined as 15° C.

The following constants were determined:—

$d_{15 \cdot 5}$ ·9972.

n_D^{20} 1·5200.

Boiling point, 252–255° C. (5 mms.).

Acid number, 143.

Saponification number, 145.

Iodine value, 120.

Combustion Results.—

Found C = 77·6 H = 9·6.

[$C_{24}H_{36}O_3$ requires C = 77·4 H = 9·7.]

Methoxyl Determination.—

·3728 gramme gave ·2244 gramme Ag.I. corresponding to one methoxyl group.

Silver Salt.—The silver salt darkened rapidly on keeping. The silver content was determined as 22·6%, corresponding to a molecular weight of 372.

Sodium Amalgam, acting in alcoholic solution, was found to have no reducing action on the acid.

Re-methylation of Pentaspadonic Acid Methyl Ether.—For the subsequent experiments the methyl ester prepared by remethylation of pentaspadonic acid methyl ether was used. Although it differed little in constants from those previously described for the methyl ester, its preparation from purified pentaspadonic acid methyl ether was deemed advisable, in order to obtain a methyl ester free from any possible impurity not eliminated in the original methylation, such as the methyl ether of a phenol.

Crystalline Tetra Hydro Methyl Pentaspadonate Methyl Ether.—In order to reduce the two unsaturated linkages and in the expectation of obtaining crystalline derivatives, pure dry hydrogen was led into a constantly shaken solution of the methyl ester (25 grammes) in ether or methyl alcohol (100 ccs.) containing in suspension ·2 gramme of platinum dioxide, an adaptation of the method of Vorhees and Adams.[5] Saturation was rapid and the passage of hydrogen continued until the solution no longer decolourised bromine. The platinum black was removed by filtration, after a preliminary shaking with air, and sufficient of the solution evaporated to allow of crystallisation on cooling. The yield of solid material was almost quantitative. After several recrystallisations from alcohol the substance separated in beautiful plates melting at 44° C.

Combustion Results.—Numerous combustion results, carried out to accurately characterise the substance, gave as a typical result—

C = 77·0 H = 10·8.

[$C_{25}H_{42}O_3$ requires C = 76·9 H = 10·8.]

Methoxyl Determination.—

·208 gramme gave ·230 gramme Ag.I.

indicating two methoxyl groups.

Molecular Weight Determination.—This was determined by the freezing point method, using benzene as solvent. Mean of several determinations, 385.

Tetra Hydro Pentaspadonic Acid.—This was obtained as a by-product from the Zeisel determination of methoxyl in the crystalline ester. After recrystallisation from alcohol it melted at 88° C. The phenolic group, being now free, reacted with ferric chloride to give a violet colour similar to that from the original acid.

Tetra Hydro Pentaspadonic Acid Methyl Ether.—This was obtained by hydrolysis of the crystalline ester, a similar hindrance to hydrolysis

[5] Journal American Chemical Society, 1922, 44, 1397.

to that noted above in the case of the unsaturated ester being shown. The acid, after recrystallisation from alcohol, melted at 85° C.

Combustion Results.—Repeated analysis gave as a typical result—

Found C = 76·7 H = 10·7.

[$C_{24}H_{40}O_3$ requires C = 76·6 H = 10·7.]

Acid Number.—The acid number was determined as 147.

Silver Salt.—The silver salt, which did not darken like the silver salts of the unreduced acids, left on ignition a residue of 22·6% of silver.

This agrees with an approximate molecular weight of 375.

Oxidation of the Unsaturated Ester, Methyl Pentaspadonate Methyl Ether.—Twenty-five grammes ester dissolved in acetone were treated gradually with finely sieved potassium permanganate (100 grammes).

The acetone solution was allowed to boil during the oxidation, which was completed at the boiling point. Separation of the precipitated manganese dioxide, containing the potassium salts of the acids produced, was followed by its repeated extraction with boiling water. The aqueous extract, which gave good qualitative tests for oxalic acid, was concentrated to a small bulk and acidified with sulphuric acid. A pronounced odour of lower fatty acid was noticed in the resulting liquor, and steam was accordingly passed in to remove volatile acids, the bulk of the acids being, however, not volatile. The volatile acid was identified as hexoic acid by the silver salt method.

(Found Ag = 48·4, silver hexoate requires Ag = 48·4.)

The non-volatile acid,[6] isolated by ether extraction, showed no tendency to crystallise.

Methoxyl Determination.—

·2054 gramme gave ·3102 gramme Ag.I.
corresponding to two methoxyl groups.

Silver Salt.—The silver salt left on ignition a residue of 25·9% of silver.

[$C_{17}H_{23}O_5Ag$ requires 26·0% Ag.]

Esterification of the Acid.—For purposes of purification and in order to test its homogeneity, the acid oxidation product was converted into methyl ester by refluxing with methyl alcohol and concentrated sulphuric acid for four hours. The resulting methyl ester was fractionally distilled, but almost the whole was collected at a constant boiling point (192° C., 5 mms.) as a colourless liquid. It was fully saturated and the high boiling point indicated a degree of complexity not far removed from the original unsaturated ester from which it was derived. It proved, however, to be the ester of a dibasic acid.

[6] The homogeneity of this acid follows from that of its dimethyl ester described later.

Combustion Results.—

Found C = 66·9 H = 8·1.

[$C_{18}H_{26}O_5$ requires C = 67% H = 8·1%.]

Methoxyl Determination.—

·1102 gramme gave ·2372 gramme Ag.I.

indicating three methoxyl groups, two as ester groups.

Hydrolysis of the Dibasic Ester.—This was effected by prolonged hydrolysis with sodium ethoxide solution during several hours, a similar hindrance to hydrolysis to that previously noted being shown. The resulting acid did not crystallise, but remained as a very viscous oil. The sample obtained in this experiment was apparently still contaminated with a small proportion of unhydrolysed mono methyl acid ester as is indicated by the silver salt determination, the percentage of silver being somewhat low.[7]

Silver Salt.—The silver salt left on ignition a residue of 36·3% of Ag.

[$C_{16}H_{20}O_5Ag_2$ requires 42·5%.]

The products obtained on oxidation of the unsaturated methyl ester were, therefore, hexoic acid, oxalic acid, and the mono methyl ester of a dibasic acid in which the methyl ester group of the original unsaturated methyl ester remained unaffected during the oxidation, the free acid group being formed in the oxidation. The retaining of the ester group unimpaired throughout the oxidation has an important bearing on the constitutional problems involved, as it indicates that the carboxyl group of pentaspadonic acid is either directly attached to the nucleus or by means of a saturated side-chain. Our choice of the methyl ester instead of the free acid (methyl pentaspadonic acid) for oxidation purposes was made in order to test this aspect of the constitutional problem; an acetone solution of permanganate being used in view of the specific disruptive action of this reagent at double linkages.

In this connection it may be mentioned that a saturated glyceride such as tripalmitin may be recovered unchanged from boiling acetone permanganate, and the oxidation experiment described here is evidently a close parallel.

The attachment of the carboxyl group of pentaspadonic acid either directly to the nucleus or by means of a saturated side-chain is also indicated by the negative action of sodium amalgam on this acid. In view of the production of oxalic acid on oxidation, any unsaturated linkage present in this side-chain must have occupied the $\alpha\beta$ position with respect to the carboxyl group, and such unsaturated acids are reduced by sodium amalgam.

Discussion of the Results.

The results of the investigation recorded in the preceding work, although insufficient to admit of definite characterisation of the

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[7] The value obtained, 36·3%, was much too close to that required for a dibasic acid to admit of any doubt as to its nature.

pentaspadonic acid, nevertheless are sufficiently complete to admit of reasonable conclusions being drawn. We have no doubt that a more detailed examination along the lines indicated (which unfortunately could not be further continued owing to exhaustion of supplies) would result in complete eludication of the constitution of this interesting acid. We have adopted the well-established procedure of placing most reliance on the analytical results obtained from crystalline products from which our formulæ have been calculated as a basis, but it will nevertheless be found that there is fair agreement with predicted results even with liquid products.

The difficulty of deciding between two homologous formulæ such as $C_{25}H_{42}O_3$ and $C_{26}H_{44}O_3$ is very real when the molecular weights[8] are high as in the present instance, but we put forward the view, as the result of our investigation, that the exudate of *Pentaspadon motleyi* consists essentially of a monohydric monobasic acid with two unsaturated linkages and of molecular composition $C_{23}H_{34}O_3$. The methyl ether of the methyl ester produced on methylation is of molecular composition $C_{25}H_{38}O_3$, and the monobasic acid (pentaspadonic acid methyl ether) produced on hydrolysis is of molecular composition $C_{24}H_{36}O_3$. Resulting crystalline derivatives obtained by reduction of the methyl ester and subsequent derivatives are respectively—

Tetrahydro pentaspadonic acid, $C_{23}H_{38}O_3$.

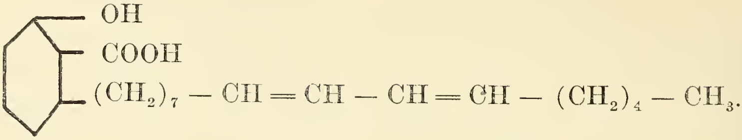
Tetrahydro pentaspadonic acid methyl ether, $C_{24}H_{40}O_3$.

Tetrahydro methyl pentaspadonate methyl ether, $C_{25}H_{42}O_3$.

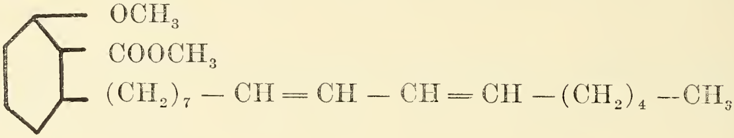
These results agree with the hypothesis of a benzene nucleus (although no simple identifiable benzene derivative has yet been isolated by us). Attached to the benzene nucleus is the phenolic hydroxyl group, and in view of the dibasic acid produced in the oxidation described two additional side-chains, one of which contains the carboxyl group and the other the two unsaturated linkages. The difficulty of esterification of the carboxyl group and the analogous stability of its methyl ester require a steric hindrance factor, and we are, therefore, of the opinion that the carboxyl group must be directly attached to the nucleus. The other side-chain, therefore, contains the whole of the remaining sixteen carbon atoms, with two unsaturated linkages, and this chain is no doubt responsible for the characteristic odour resembling fish oil. The steric hindrance factor, noted in all the products described whether saturated or not, seems further to require that the three groups attached to the nucleus occupy the 1:2:3 positions, but we have no other confirmation of this view, which is therefore tentative. Assuming therefore that the oxalic acid produced in the oxidation is a primary and not a

[8] Molecular weight determinations do not admit of an accuracy within 10% in such cases.

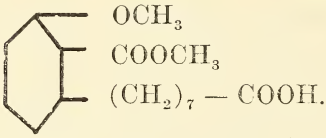
secondary oxidation product, we are led to suggest the following structure for pentaspadonic acid—



The methylated derivative (the unsaturated methyl ester) would then have the structure—



and the acid obtained on oxidation—



We would emphasise that no finality is claimed for this structure of pentaspadonic acid, but it is hoped, if further supplies of material should become available, to continue our work until a final decision can be made.

Reference should be made to the results described by Penfold and Morrison (loc. cit.), in which a molecular composition $C_{24}H_{36}O_4$ is assigned to crude acid isolated from the exudate.

As this formula is based on analysis of crude material, it can make little claim to accuracy and the supposition made by these authors of the presence of two hydroxyl groups is equally erroneous. Our results clearly indicate the presence of but one such group, and this seems also to be borne out by the acetyl values quoted in Penfold and Morrison's paper.

With respect to the negative economic value of the exudate we are in agreement with the views of these authors. Pentaspadonic acid may, however, possess some antiseptic value in view of its phenolic group and similarity of structure to salicylic acid. Of interest in this connection is the use by Malayan natives of the exudate of *Pentaspadon officinalis* mentioned in the introductory section of the paper.

It may finally be observed that the oil possesses little value as a drying oil, the methyl ester remaining practically unchanged for considerable periods on exposure to air.

The authors wish to record their thanks to Messrs. White and Francis, of the Government Botanical Staff, for their contributions towards the botanical investigation; to Mr. Lane-Poole, for his original supplies of the exudate; and to Mr. A. R. Penfold, Technological Museum, Sydney, who generously placed his residual supply of exudate at our disposal.

Some Experiments on the Treatment of Tick-infested Cattle with Arsenical Dipping Fluids.

By John Legg, Government Veterinary Surgeon,
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(*Communicated by Mr. F. A. Perkins, B.Sc.Agr., to the Royal Society of Queensland, 24th June, 1929.*)

INTRODUCTORY.

The experiments and observations recorded in this paper deal with the use of solutions of sodium arsenite in the treatment of tick-infested cattle under field conditions, the fluids being applied by immersing the animals in a dipping vat containing the solution under test. The efficacy of any particular line of treatment was determined by collecting all female adult ticks reaching maturity subsequent to treatment, testing these adults for viability by segregating them and determining their ability to oviposit fertile eggs, and comparing these adults both in number and quality with adults obtained from control cattle not subjected to treatment.

A word is perhaps necessary as to the circumstances under which the work was carried out. The dipping vat, an ordinary concrete one containing about 2,200 gallons when full, and having associated with it the usual holding yard, crush, and draining pen, was centrally situated in regard to a small group of well-fenced paddocks. This group of paddocks, protected partly by the high banks of a tidal river on two sides, by a double line of fencing on a third side, and almost wholly enclosed on the fourth side by cultivation paddocks, had been free of ticks for several years prior to the commencement of our experiments. Its situation was ideal for the conduct of the work in hand.

Into this area we introduced, from a remote area outside, many naturally infested cattle carrying large numbers of parasites in all stages of development, and although as the work proceeded we found that some paddocks became infested—particularly those paddocks used for cattle undergoing a course of two dippings, and where there was no attempt to collect ticks reaching maturity between treatments—it was always found possible to close these down and use other clean paddocks, and so carry the work forward.

All treated cattle were allowed grazing under natural conditions after any particular line of treatment, being crush-inspected at least once daily, or more often if thought necessary; and all female adults as they reached maturity were collected. We believe that the methods adopted by us were such as to prevent any female adult from reaching a state of repletion on any of the treated cattle, and leaving the host without being caught at one or other of the examinations which were continued until one could be absolutely certain that the animals were quite free of parasites.

Control cattle were stalled. This was necessary to prevent pasture contamination, as it was utterly impossible to collect 100 per cent. of adults reaching maturity on these animals. These adults were set aside in large containers and many millions of larvæ produced. When due allowance was made for ticks destroyed or damaged during removal, the number of these adults which proved to be ordinary viable ticks can be set down as approximately 100 per cent. Control cattle were usually clean by the twenty-eighth day after stalling.

Artificially infested cattle were necessary in some experiments, but otherwise the work was performed with naturally infested animals, and it will be noted in many cases that an attempt has been made to classify these animals—certainly a difficult proposition—according to type of infestation, the terms "very heavy," "heavy," "moderate," and "light" being used. Such terms are only relative, but when the controls are examined they convey some idea as to the number of parasites carried by any particular animal.

The whole of the work was conducted in a manner strictly in accordance with the ordinary methods of field practice.

EXPERIMENT I.—TO DETERMINE THE EFFECT OF TREATMENT ON THE TICK AT DIFFERENT PERIODS OF ITS PARASITIC LIFE.

In order to interpret the results of this experiment correctly, it is necessary to have a clear idea of the main features concerning the parasitic life of the tick.

When cattle are artificially infested, it is found that the larval ticks engorge rapidly during the first four days, and by the fifth day are replete, and have reached a stage just prior to moulting. Odd nymphs appear on the sixth day, but are usually not present in any great number until the seventh day.

The transition period from larvæ to nymphs is short, usually occupying about 48 hours. On many animals nymphs only are present on the ninth day. During the following three days the nymphs engorge rapidly, and young adults may appear on the thirteenth day. Many animals show a considerable number of young adults by the fourteenth day.

The moulting of the nymphs is a process which is spread over several days. Thus, although young adults appear on many animals by the fourteenth day, nymphs can still be found, and sometimes in considerable numbers, up to the seventeenth day. On the eighteenth day, although nymphs are uncommon as a rule, they can occasionally be seen, and odd ones may be found up to the twentieth day.

The period of parasitism of the female adult is at least six days and usually seven to nine days.

The above conclusions have been arrived at after a series of observations carried out during 1926 and 1927 by one of us (J.L.), and they correspond fairly closely to the parasitic life history of the American cattle tick as recorded by Graybill and others.

In November, 1927, fifteen young cattle, ranging from one to three years of age, and all of which had been subject to moderately heavy natural infestation over a considerable period of their lives, were selected, cleansed of ticks, and then allowed grazing under circumstances which precluded any possibility of natural infestation.

Several weeks afterwards, when their skins had cleaned up and the cattle had improved considerably in condition, they were heavily infested with larval ticks raised artificially in the laboratory. Each animal received several thousand larvæ. After infestation the animals were again allowed to graze naturally, and periodic "crush" inspections showed the ticks to be developing in a perfectly normal manner. Hundreds could be counted on most animals.

The dipping fluid used contained 8 lb. arsenic (As_2O_3), 4 lb. caustic soda, 1½ gallon Stockholm tar, and 2 lb. hard soap per 400 gallons.

The cattle were divided into groups, and dipped once at various periods as shown below:—

		Condition of Ticks.
Group 1.— 6th day ..	3 animals ..	In engorged larval state.
Group 2.—10th day ..	3 animals ..	In young nymphal state.
Group 3.—14th day ..	2 animals ..	Mostly in engorged nymphal state some young adults present.
Group 4.—17th day ..	2 animals ..	Mostly in young adult state; a few engorged nymphs.
Group 5.—19th day ..	2 animals ..	In adult state; some in latter half of parasitic adult stage.
Group 6.—21st day ..	2 animals ..	Mostly in last half of parasitic adult stage; some younger adults also present.

One animal was retained as a control.

It should be added here that, as many female ticks were rapidly approaching maturity, the animals which were to be dipped on the twenty-first day as well as the control were removed from pasture at the end of the nineteenth day to prevent pasture contamination. Similarly, those cattle dipped on the nineteenth day were also removed from pasture directly after being dipped. All five cattle were placed in stalls and fed artificially during the rest of the experiment.

After treatment all cattle were subject to close and frequently repeated inspection, and as female adults became engorged they were removed just prior to natural detachment, segregated in the laboratory, and their subsequent history followed. Where female ticks were engorging in large numbers, as happened in the case of some of the stalled cattle, it was only natural that a few should be lost in the bedding during the night, but the number obtained was sufficient to warrant our conclusions.

In the case of one animal (No. 282) dipped on the twenty-first day, many females were obviously within a few hours of complete engorgement at the time of treatment, and some of them had actually reached this stage. Probably a few females had dropped from the animal into the bedding during the previous 24 hours.

The results are set out in the following table (Table Ia). In reading this table it will be noted that we have kept separate each daily (24-hour) batch of engorged females and have calculated the number which oviposited, number of eggs, &c. Females which fail to oviposit can easily be distinguished, and are removed as they die from the containers. From the mass of eggs produced an average is made as to the number supplied by each female, usually by weighing the egg mass and calculating on the basis of 25,000 eggs to the gram. The mass of eggs is then supplied with moisture, and if hatching takes place a rough estimate as to the percentage of fertile eggs is made from a macroscopic appearance of the mass. This method is one which is adopted throughout this paper, and although it does not give the total number of female survivors which oviposit fertile eggs, because many females which oviposit fail to produce fertile eggs, it does give a rough estimate of the actual number of larvæ produced from the surviving ticks from different animals.

Table Ia.

Table showing the Effect of a Single Dipping on Ticks in Various Stages of Development.

8 lb. arsenic (As_2O_3), 1½ gallon tar, 2 lb. hard soap, caustic soda q.s. per 400 gallons of solution.

November, 1927.

No. of Animal.	Age of Ticks in Days at date of dipping.	Day after Infestation (Ticks removed).	Number of Engorged Females.	Number of Females Ovipositing.	Average Number of Eggs.	Approximate % Hatching.	Longevity of resultant Larvæ Days.	Remaks.
292	6*	No engorged females removed.						
293	6							
294	6							
289	10	No engorged females removed						Total engorged females, 8. Total engorged females ovipositing, 7.
290	10	24th	1	1	600	90	40	
291	10	24th	1	1	1,000	80	25	
		26th	1	2	800	Nil	..	
		28th	1	1	400	Nil	..	
		29th	2	2	250	60	10	
		33rd	1	Nil	..	..	..	
287	14	No engorged females removed						Total engorged females, 2. Total engorged females ovipositing, 1.
288	14	25th	2	1	300	Nil	..	
285	17	29th	1	1	250	Nil	..	Total engorged, 1. Total ovipositing, 1.
286	17	No engorged females removed						
283	19	25th	1	1	500	Nil	..	Total engorged females, 15. Total engorged females ovipositing, 12.
		26th	1	Nil	..	..	..	
284	19	25th	3	2	200	Nil	..	
		26th	4	3	800	50	48	
		24th	6	6	1,000	90	29	
281	21	22nd	481	431	·750	Nil	..	Total engorged females, 1,077. Total engorged females ovipositing, 936.
		23rd	136	117	2,000	50	68	
		24th	26	24	1,750	50	72	
		25th	13	11	1,600	75	71	
		26th	2	Nil	..	..	..	
282	21	22nd	208	176	1,400	10	55	
		23rd	124	119	1,600	20	55	
		24th	54	25	2,000	75	68	
		25th	22	22	1,000	75	57	
		26th	10	10	800	75	71	
		28th	1	1	600	60	34	
295	Control		Total engorged females removed, 809; approximately 100 per cent. viable.					

* The actual immersion or dipping of the animals was carried out at the *end of the twenty-four hour period* representing the sixth day, tenth day, &c.

We consider the following observations are worth recording:—

In the case of those cattle dipped on the sixth day, a few ticks (about one dozen altogether) continued to develop, and some actually reached the young adult stage. They did not appear to be capable of developing further and were all dead before the twenty-seventh day.

On those cattle dipped on the fourteenth day, many nymphs moulted after dipping (about 200 altogether), and reattached. A few partly engorged, but except for those recorded as having reached a stage of repletion the remainder died before reaching complete maturity. The animals were all clean on and after the thirty-fifth day.

On a second occasion during the month of April, when the dipping vat was charged with a well-known proprietary solution at the rate of 8 lb. arsenic (as As_2O_3) per 400 gallons, together with certain emulsifying bodies, the experiment was repeated.

Three animals were dipped on the sixth day, three on the tenth day, three on the fourteenth day, two on the seventeenth day, two on the nineteenth day, and two on the twenty-first day after infestation. The results are summarised as follows:—

Group I.—Three animals dipped sixth day after infestation. No ticks reached maturity.

Group II.—Three animals dipped tenth day after infestation. One animal yielded no ticks, a second animal yielded an engorged female on the twenty-third day after infestation, which tick oviposited approximately 900 eggs, of which 40 per cent. hatched. The third animal yielded two female ticks on the thirty-second day after infestation, which ticks oviposited an average of 600 eggs each, of which 75 per cent. hatched.

Group III.—Three animals dipped fourteenth day after infestation. Two animals yielded no ticks while the third yielded five (on the twenty-fourth and twenty-fifth days). Of this number one tick failed to oviposit, while the other four oviposited an average of 800 eggs each, of which 60 per cent. hatched.

Group IV.—Two animals dipped seventeenth day. One animal yielded three ticks, two failing to oviposit, the other ovipositing approximately 1,200 eggs, which proved non-fertile. The other animal yielded one tick on the twenty-fourth day, which tick oviposited approximately 1,200 eggs, of which 80 per cent. were fertile.

Group V.—Two animals dipped nineteenth day. One animal yielded 403 engorged females (twenty-first and twenty-fifth days), of which 328 oviposited an average of 2,000 eggs, the remaining ticks failing to oviposit; 50 per cent. of the eggs proved fertile. The other animal yielded 136 engorged females, of which 60 oviposited an average of 2,000 eggs, 40 per cent. of eggs proving fertile.

Group VI.—Two animals dipped twenty-first day. One animal yielded 193 engorged females, 184 of which oviposited an average of 1,600 eggs, 20 per cent. of eggs proving fertile. The other animal yielded 385 engorged females, of which 120 oviposited an average of 1,200 eggs, 20 per cent. of eggs proving fertile.

The controls yielded 914 and 298 engorged females respectively, 100 per cent. of which were normal viable ticks.

In order to obtain further evidence on the same point, we treated two naturally infested animals (Nos. 316 and 317) carrying ticks in all stages of development as shown in the Table below. After treatment these two animals with the controls were examined for maturing females, which were set aside for further observation. The results are shown in Table Ib:—

TABLE IB.

Dip contained 8 lb. arsenic, 1½ gallon Stockholm tar, 2 lb. hard soap per 400 gallons.

November, 1927.

Day after Dipping.	Number of Ticks removed.	Number Ovipositing.	Average Number of Eggs.	Average % Hatching.	Longevity of Larvæ (days).	Remarks.
				No. 316.		
1st	26	14	1,400	20	77	Animals examined daily up to twenty-eighth day after treatment.
2nd	22	14	1,000	40	35	
3rd	7	2	100	Nil	..	
17th	1	1	400	Nil	..	
19th	2	2	500	80	56	
				No. 317.		
1st	86	48	1,000	Nil	..	No engorged ticks found after fourth day.
2nd	14	10	1,300	50	73	
3rd	4	Nil	..	..	..	
4th	5	2	400	80	70	

Controls—
No. 318—3,561 }
No. 319—3,181 } engorged females removed; approximately 100 per cent. viable.

DISCUSSION.

Examining the first two experiments together, we note the following:—

No ticks reached maturity on any of the cattle carrying ticks six days old. Odd ticks reached maturity on the cattle dipped on the tenth day. Some of these ticks produced viable eggs. From the five cattle dipped on the fourteenth day, a small number of mature ticks was again obtained, some of these also ovipositing viable eggs. Similarly, the cattle dipped on the seventeenth day produced but few mature females.

On the nineteenth day and after, however, the number of survivors is liable to be markedly increased. With the dipping fluid containing Stockholm tar and soap as adjuvants, there were not so many survivors as when the cattle carrying ticks of the same age were dipped in the proprietary mixture, but we are not prepared to say that this indicates any great difference in the "tickicide" value of the medicaments concerned. It has been noted that, when a number of cattle are artificially infested, with some individual animals the parasitic period of the tick is apparently slightly shorter on the average than with other cattle; thus the first engorged females appear on some during the twentieth day, whilst others do not give rise to similar female ticks until the twenty-second day or even later. This variation may account for the apparent difference between the cattle dipped in the two medicaments on the nineteenth day, because it appears to be somewhere about this time, i.e., the nineteenth day, when the female adult has completed about three or four days of parasitism, or is about halfway through the parasitic adult period, that its resistance to treatment with arsenical fluids increases.

All the four cattle dipped on the twenty-first day yielded large numbers of engorged females, and although the mortality amongst these was high, there still remained a large number of females which oviposited viable eggs in considerable quantities. The larvæ arising from some of these eggs when tested for longevity lived for many weeks, and presented no difference from larvæ raised from normal females.

Seeing that the female adult tick spends at least six days* and usually seven to eight attached to its host, its period of resistance corresponds to approximately the last half of parasitic adult life.

Cohen[3], in a series of observations on naturally infested cattle sprayed and dipped in various strengths of arsenical dipping fluids, drew the conclusion amongst others that the surviving females mostly represented ticks which were in the pre-adult stage at the time of treatment. He advanced the suggestion that the engorged nymph just prior to moulting was protected by the skin of the old moult, or, in other words, was doubly protected by the two integuments.

This observer apparently did not examine his experimental cattle for a longer period than five days after treatment, during which period no female in the pre-adult stage at the time of treatment could possibly reach maturity. It appears, too, that none of the surviving females were tested in regard to their ability to oviposit fertile eggs.

The weight of evidence, we think, is entirely opposed to such an hypothesis. In the first place those cattle treated on the fourteenth and seventeenth days—particularly those treated on the fourteenth—carried numbers of ticks in a stage just prior to moulting, yet only odd ticks reached maturity on these animals. Examination showed that within forty-eight hours these nymphs, as well as the young recently hatched adults, were mostly dead and commencing to shrivel up while still attached to the host.

Secondly, if this theory regarding the greater resistance of the tick during or just prior to the second moult were correct, then, when naturally infested cattle carrying ticks *in all stages* are treated with standard arsenical dipping fluids—seeing that the average female occupies seven to nine days of parasitism, and there is no reason to believe that this period is shortened by the application of arsenical dipping fluids—there should be a greater number of females reaching

* This period has been determined by one of us (J.L.) after observations made on some thousands of ticks.

maturity during the *second week* after treatment than during the first week, for it will be during the second week that such resistant ticks ultimately reach maturity.

If we refer to Table IB. we find that this does not happen, but that the great majority of survivors capable of producing fertile eggs not only reach maturity during the first week, but *during the first half of that week or the three or four days immediately following treatment.* Field evidence therefore supports the view we have expressed.

It has been clearly shown that if artificially infested cattle are treated at a time when the whole of the nymphs have moulted (nineteenth and twenty-first day after infestation), and when large numbers of females are within two or three days of reaching maturity, the number of survivors from such animals capable of producing fertile eggs is considerably greater than when similarly infested animals are treated when the parasites are in an earlier stage of development (sixth, tenth, fourteenth, and seventeenth days).

Although we speak of the tick as being in a resistant stage during the last three or four days of parasitic life, the term is only used in a comparative sense. That the vast majority of ticks, even up to nearly 100 per cent., in all stages of parasitism may be occasionally destroyed by a single application of a medicament containing much less arsenic than the standard dip, will be shown later on in this paper.

Conclusion.—The female adult tick, particularly during the last two to four days of parasitic life, or what corresponds to the last half of parasitic adult life, is much more resistant to treatment with arsenical dipping fluids than at any previous period of parasitism.

EXPERIMENT II.—TO DETERMINE THE EFFECT OF TREATMENT IN PREVENTING INFESTATION WITH LARVAL TICKS.

The eighteen animals used in the first part of this experiment had previously been naturally infested with ticks over a prolonged period. They were cleansed of the parasites and placed in a clean paddock for approximately three weeks, during which time they improved somewhat in condition.

The medicament used contained 7 lb. arsenic (as As_2O_3) per 400 gallons, 1½ gallon tar, 2 lb. hard soap, caustic soda q.s. The experiment was carried out in December.

After dipping the cattle were divided into nine groups of two each. Eight groups were infested as follows:—One each at the end of the third, sixth, twelfth, eighteenth, twenty-fourth, forty-eighth, and seventy-second hour after dipping. The two animals in the control group yielded 279 and 234 engorged females respectively. No ticks reached engorgement on any of the dipped cattle, except in the case of one animal infested seventy-two hours after dipping. This animal produced three female adult ticks, all of which oviposited, yielding an average of 2,000 eggs, of which 50 per cent. proved fertile.

A second experiment was carried out in January, the medicament on this occasion varying somewhat from the above experiment in that it contained 6 lb. arsenic (as As_2O_3) per 400 gallons; double the quantity of emulsion, however, was added to the dipping solution—i.e., 3 gallons tar, 4 lb. hard soap, &c. Fifteen animals were used, of which two constituted controls and yielded fourteen and twenty engorged female adults respectively. Of the remaining thirteen which were dipped, two were infested at the twenty-fourth hour, three at the forty-eighth hour, three at the seventy-second hour, two at the ninety-sixth hour, and three at the one hundred and twentieth hour following treatment.

Of the three animals treated at the forty-eighth hour, one yielded two female adults, both of which oviposited approximately 1,000 eggs, 80 per cent. of the resultant mass of eggs proving fertile. Of the three cattle infested at the seventy-second hour one yielded no adults, the second yielded five, all of which oviposited, yielding an average of 1,500 eggs, with a 70 per cent. fertility of the mass of eggs produced, while the other animal produced one adult which oviposited approximately 1,000 eggs, with a 75 per cent. fertility. None of the other animals yielded adult female ticks.

We are not able to give any explanation as to why so few ticks reached maturity on the controls.

The observation was repeated for a third time in May, the dipping solution on this occasion containing 6 lb. arsenic (as As_2O_3) per 400 gallons, 1½ gallon tar, &c., eleven animals being used, of which one served as a control and yielded 4,625 engorged female ticks. After dipping, the ten animals were divided into groups and infested at the twenty-fourth hour (three animals), forty-eighth hour (two animals), seventy-second hour (two animals), and ninety-sixth hour (three animals).

No ticks reached maturity on the cattle infested at the twenty-fourth hour.

One animal infested at the forty-eighth hour yielded one female, ovipositing approximately 800 eggs, of which 90 per cent. proved fertile.

Of the two animals infested at the seventy-second hour, one yielded five ticks which oviposited an average of 800 eggs each, 90 per cent. of the resultant egg mass proving fertile, while the other yielded one tick which oviposited approximately 200 eggs, of which 75 per cent. hatched.

Of the three animals treated at the ninety-sixth hour, all yielded fertile ticks. One yielded 100 adults, ninety-seven of which oviposited an average of 1,800 eggs, with a fertility of 90 per cent.; the second yielded eleven adults, six ovipositing an average of 600 eggs, with a 90 per cent. fertility; while the third yielded four adults, one of which oviposited 1,500 eggs, with a 75 per cent. fertility.

Discussion.

The experiment shows that cattle can be infested with larval ticks forty-eight hours after treatment in dipping solutions containing considerable quantities of arsenic, together with an emulsion of tar and soap.

Although no larval ticks developed on those cattle infested up to the forty-eighth hour in the first experiment, in the second experiment, when the amount of emulsion was doubled, one animal infested at the forty-eighth hour eventually produced two mature viable female ticks.

In the third experiment the cattle infested at the twenty-fourth hour again remained clean of parasites, whilst some of those infested at the forty-eighth hour or later produced mature adults capable of ovipositing fertile eggs.

Conclusion.—Up to the twenty-fourth hour after treatment in solutions of arsenic of a strength approximating that of the standard dip (8 lb. As_2O_3 per 400 gallons), and containing considerable quantities of emulsion of tar and soap, cattle remain immune to infestation with larval ticks. At the forty-eighth hour or later infestation is liable to occur.

EXPERIMENT III.—TO DETERMINE WHETHER ANY BENEFICIAL EFFECT IS PRODUCED ON THE TICK BY PERMITTING CATTLE TO ENTER WATER SOON AFTER TREATMENT.

After considerable field experience in the treatment of tick-infested cattle with arsenical dipping fluids, we have been led to form the conclusion that, if recently treated cattle are allowed to enter water, the effect of the treatment (as might naturally be expected) is seriously interfered with. We have noticed that during the months of January, February, and March in North Queensland many cattle have a habit of standing for long hours during the day almost wholly immersed in water. They do this as a rule to avoid the attacks of biting flies.

Travelling cattle which are dipped at various points on the main stock routes in Queensland, when such cattle are being moved from tick-infested to clean country, are usually yarded overnight and dipped the following morning. As the dips are frequently built on the banks of lagoons or where there is a considerable quantity of surface water, it not infrequently happens that treated cattle, soon after being released from the draining pens, proceed to the drinking water and enter it if permitted. An experiment was therefore designed to test the effect of permitting cattle to enter water after having recently been treated.

Seventeen head of cattle were used, fifteen being treated twice with a five-day interval in a fluid containing 7 lb. arsenic (As_2O_3), 3 gallons Stockholm tar, 4 lb. hard soap, caustic soda q.s. per 400 gallons. Ten animals were allowed to enter water within a few minutes after each treatment and remained therein for one hour; the other five animals were precluded from doing so. Two untreated beasts acted as controls. After treatment all the cattle were placed under circumstances which prevented natural infestation, were allowed grazing, and examinations continued for a month after removal from tick-infested pasture.

No record was kept of ticks reaching maturity between the two dippings. The observation was carried out in March, 1928. The results are set out in the following table (Table III.) :—

TABLE III.

TO SHOW THE EFFECT OF PERMITTING RECENTLY TREATED CATTLE TO ENTER WATER.

Dipping fluid : 7 lb. arsenic, 3 gals. tar, 4 lb. hard soap, caustic soda q.s. per 400 gallons.

March, 1928.

No. of Animal.	Type of Infestation.	Interval between Treatments.	Total Mature Females Collected.	Total Females Ovipositing	Average Number of Eggs.	Average Number of Eggs Hatching.	Longevity of resultant Larvæ in days	Remarks.
442	Moderate	5 days	231	207	1,500	75	24	Entered water and remained therein for one hour after each treatment.
443	Heavy ..		91	76	2,000	60	22	
444	Moderate		44	33	1,500	75	[illegible]	
445	Moderate		110	92	1,800	75	41	
446	Heavy ..		52	45	1,200	90	77	
447	Moderate		68	56	2,000	75	47	
448	Moderate		120	119	1,500	50	58	
449	Light ..		174	160	1,500	75	73	
450	Moderate		98	87	2,000	90	63	
451	Heavy ..		241	222	1,200	75	67	
*425	Moderate		4	2	1,000	20	47	Did not enter water after treatment.
426	Heavy ..		Nil	..	..	..	..	
427	Moderate		Nil	..	..	..	..	
428	Heavy ..		Nil	..	..	..	..	
429	Heavy ..		1	Nil	..	..	..	
440	Moderate	Controls	8,177	Approximately 100 per cent. viable.				
441	Moderate		6,468					

* These animals (Nos. 425-429, 440, 441) also appear in Table VIIK. All the animals shown in Table VIIK. as well as the above belonged to the same lot of cattle i.e., they had all been exposed to natural infestation over a similar period of time, in the same paddock, and removed on the same day. One group of controls only was therefore necessary. Collection of ticks commenced immediately after the second treatment.

DISCUSSION.

There is no difficulty in drawing conclusions from the above experiment. The dipping fluid killed an enormous number of ticks on all animals, and actually only quite a small percentage of the parasites escaped destruction (compare with controls) but the difference between the two groups is quite distinct and marked.

It might be considered that, by allowing the animals to remain in the water for an hour partly or almost totally immersed, one is producing a condition of affairs not seen under natural conditions, but this is not so. We have observed cattle enter water in the fly season and remain therein during the whole of the hours of daylight, only coming out to graze after sunset.

The water into which the cattle in the above experiment were driven was not of sufficient depth to totally immerse the animals, as it was only 3 ft. 6 in. to 4 ft. deep. With most of the animals the water came up to approximately the level of the shoulder joint. It was noticeable that practically the whole of the survivors were removed from those portions of the body which were immersed, while on the upper or exposed portions the ticks were almost wholly destroyed.

Conclusion.—Permitting cattle to enter water immediately after dipping and remaining therein for considerable periods seriously interferes with the efficacy of the treatment.

EXPERIMENT IV.—TO DETERMINE THE EFFECT OF RAINFALL ON RECENTLY TREATED CATTLE.

The dipping fluid used in this experiment contained 8 lb. arsenic (as As_2O_3), 1½ gallon Stockholm tar, 2 lb. hard soap, caustic soda q.s. per 400 gallons of solution.

Eighteen head of cattle which had been exposed to heavily infested pasture for a month were removed on the 24th November, 1927, and seventeen dipped in the ordinary manner.

After treatment, sixteen were divided into groups of two each, and gently sprayed for ten minutes from a half-inch hose, the spray being made to simulate as nearly as possible a light shower of rain both in volume and the angle at which it was directed on to the body of the animal. The interval allowed between dipping and spraying with water is shown in the following table.

After spraying, the cattle were allowed to graze under natural conditions, and were periodically crush-inspected, so that female ticks were collected and placed aside for further observation.

The results are set out in the following table (Table IVA.) :—

TABLE IVA.

November.

No. of Animal.	Type of Infestation.	Interval between Dipping and Spraying.	Number of Fertile Ticks Removed.			
			1st Week.	2nd Week.	3rd Week.	4th Week.
320 321	Heavy Light	½-hour	17	24	8	Nil
322 323	Moderate Light	1 hour	78	50	10	Nil
324 325	Heavy Moderate	2 hours	72	32	1	Nil
326 327	Moderate Heavy	3 hours	72	36	19	Nil
328 329	Light Moderate	6 hours	77	7	2	Nil
330 331	Moderate .. Very heavy	12 hours	84	24	12	1
332 333	Light Light	18 hours	Nil	1	Nil	Nil
334 335	Light Heavy	24 hours	2	3	4	Nil
336	Very heavy	Dipped only	27	Nil	Nil	Nil
337	Light ..	Not dipped or sprayed	667	199	96	35

The evidence from the above table shows in the first place that the mortality among all ticks on all treated cattle was high, this being obvious from the number of ticks obtained from the untreated control. The animals sprayed on the eighteenth and twenty-fourth hours after treatment actually showed a higher mortality amongst the parasites than the dipped control. It was obvious that with these two groups at least the spraying produced no beneficial effect, and the arsenical solution had already worked its effect before the spray was applied.

With all the other groups, however—that is, those sprayed up to the twelfth hour—a considerable number of ticks appeared to be benefited. During the first week nearly all the survivors came off within the first two or three days following treatment, after which there was a short period covering the second half of the week when few ticks were removed. During this period, however, a number of ticks—mostly half-grown adults—which had been previously showing little signs of life, began to increase in size and show evidence of recovery. Many of these reached a state of repletion during the second week following treatment. The larger number of ticks reaching maturity during the second and third week following treatment was evidently due to the beneficial effect of the spray.

We repeated the experiment with certain modifications in May, using thirty animals, including two controls. The results are set out in the following table (Table IVb.) :—

TABLE IVb.

Arsenic (As_2O_3) 6·6 lb., Stockholm tar $1\frac{1}{2}$ gal., hard soap 2 lb., caustic soda q.s. per 400 gallons.

May.

No. of Animal.	Type of Infestation.	Interval between Dipping and Spraying.	Number of Fertile Ticks Removed.			
			1st Week.	2nd Week.	3rd Week.	4th Week.
511 512 513 514	Heavy Moderate Heavy Heavy	Dipped but not sprayed	453	8	Nil	Nil
515 516 517 518	Light Light Heavy Light	Sprayed immediately after dipping	67	218	66	16
527 528 529 530	Light Heavy Light Moderate	1 hour	141	49	24	9
531 532 533 534	Heavy Light Heavy Light	2 hours	180	33	30	6
535 536 537 538	Heavy Light Heavy Moderate	3 hours	60	23	32	5
523 524 525 526	Light Heavy Moderate Moderate	4 hours	451	46	30	14
519 520 521 522	Light Light Moderate Light	5 hours	Nil	11	2	9
539 540	Light Moderate	Controls	3,697	3,333	2,696	593

Discussion.

The results from the second experiment largely confirm those obtained from the first. They show firstly a high mortality among all ticks which had passed through the dipping solutions. With the four cattle which were dipped only (and not sprayed) nearly all the survivors were removed during the first four days after treatment, thus confirming the result of Experiment No. I., which indicated the resistance of the female adult tick during the last four or five days of parasitic life. With all other groups, too, it was noted that nearly all the survivors collected during the first week came off during the first two or three days after treatment.

With all groups sprayed with water there was a tendency for a number of ticks to reach maturity during the second, third, and fourth weeks after treatment, which ticks would have apparently been destroyed had not the spraying been carried out. In some cases the number was actually higher than the number obtained during the first week.

When the two experiments are taken together, we think the following conclusions can be drawn:—

Conclusions.—

1. Even when cattle are treated when a shower is actually falling, the tick mortality still remains high.

2. Up to the twelfth hour after treatment light showers may benefit the tick, but only to a slight extent.

3. Light showery weather would not seriously interfere with the efficacy of the treatment.

EXPERIMENT V.—TO DETERMINE THE EFFECT OF INCREASING THE LENGTH OF THE DIPPING VAT (OR CAUSING THE ANIMALS TO REMAIN IMMERSED IN THE DIPPING FLUID FOR A LONGER PEROD).

It was considered, that if any variation occurred as a result of alteration in the length of the dipping vat, this variation would be just as appreciable with a dipping fluid containing smaller quantities of arsenic than that prescribed for the standard dipping fluid as when the standard solution itself was employed. Hence the strength of the fluid for this experiment was fixed at 5 lb. As_2O_3 per 400 gallons, and to this fluid was added 1½ gallon Stockholm tar and 2 lb. hard soap as emulsion per 400 gallons.

Twenty-two head of cattle, including two controls, were employed. Ten animals were allowed to swim straight through the vat, while ten others were retained in the vat at its deepest part by means of a rope attached to the tail of the beast. While being retained in the dip the animal was forced completely below the surface two or three times by means of pressure applied to the middle of the dorsal region. Each animal was retained for from ten to fifteen seconds—*i.e.*, a sufficiently long enough period to swim through a vat at least three times the length of the one employed by us.

After treatment, grazing was allowed and observations carried out for twenty-eight days, under circumstances which precluded natural infestation.

The experiment was performed in April, 1928.

The results are set out in the following table (Table V.) :—

TABLE V.

Dipping fluid : Arsenic (As_2O_3) 5 lb., Stockholm tar 1½ gallon, soap 2 lb., caustic soda q.s. per 400 gallons.

April, 1928.

No. of Animal.	Type of Infestation.	Treatment.	Engorged Females Removed First Week. Days. 1	2	3	4	5	6	7	Total	Number Ovipositing	Average Number of Eggs.	Average % Hatching.	Remarks.
489	Heavy ..	Allowed to pass through dip in ordinary manner	..	10	17	..	..	..	..	27	3	200	90	
490	Moderate		15	5	..	..	..	..	..	20	4	150	50	One tick removed from 490 on tenth day ; no oviposition.
491	Moderate		4	6	..	..	3	..	..	13	Nil	..	..	
492	Light ..		..	..	..	..	..	..	..	..	..	..	..	
493	Moderate		32	7	4	..	..	..	..	43	14	900	40	
494	Moderate		14	4	..	..	..	..	..	18	5	800	Nil	
495	Light ..		4	..	..	..	..	..	..	4	1	400	Nil	
496	Moderate		19	3	..	..	..	..	..	22	8	500	Nil	
497	Light ..		4	13	..	..	..	..	..	17	11	900	90	
498	Moderate		4	..	2	..	..	..	..	6	2	100	Nil	
499	Moderate	Retained in dipping vat for at least 10 seconds longer than ordinarily	18	2	1	..	..	..	..	21	2	600	Nil	
500	Moderate		2	..	..	..	..	..	..	2	Nil	..	..	
501	Moderate		54	14	2	..	..	..	..	70	14	700	Nil	
502	Moderate		4	8	1	..	..	..	..	13	5	500	Few	One tick removed from 504 on twelfth day laid 300 eggs which failed to hatch.
503	Light ..		..	4	..	..	2	..	..	6	2	150	50	
504	Moderate		4	4	..	..	..	..	..	8	4	300	Nil	
505	Light ..		10	4	1	..	..	..	..	15	5	300	Nil	
506	Light ..		32	..	..	..	..	..	..	32	1	400	Nil	
507	Moderate		10	..	1	..	..	..	..	11	1	600	Few	
508	Moderate		19	2	2	..	..	..	..	23	5	600	Nil	

No. of Animal.	Type of Infestation.	Treatment.	First Week.	Second Week.	Third Week.	Fourth Week.	Total
509	Light ..	Controls	2362	1399	216	89	4066
510	Light ..	Controls	3359	2292	1320	72	7043

NOTES.—1. No other ticks were removed from any animal except those shown in the table. The last tick which might have oviposited viable eggs was removed, as the table shows, on the fifth day after treatment. The whole of the nymphs and larvæ on the treated cattle were therefore completely destroyed.

2. The two " light " controls were evidently classified on the low side and should have been classed as " moderate " or " heavy " infested animals. The experiment was carried out in the early winter when the hair was long, and it was not easy to classify the cattle as many of the smaller ticks were not obvious. Possibly the classification of the treated cattle was also on the low side as it was the invariable custom, where any doubt existed, to class the animal in the lower rather than in the higher category.

3. The longevity of the larvæ from surviving ticks was not determined.

Discussion.

The experiment calls for little comment. The results show in the first place that a single dipping in a solution containing 5 lb. arsenic per 400 gallons may be a highly toxic fluid so far as the tick is concerned, and in this respect compares very favourably with dipping fluids containing considerably larger quantities of arsenic. For the first three days some of the cattle yielded a number of females which oviposited and produced viable eggs, but afterwards only very few ticks were discovered on any of the treated animals, while the controls continued to yield large numbers of normal female ticks.

It is worth noting that considerable numbers of ticks—small female adults mostly—were not entirely destroyed at the time of treatment, but remained alive in a semi-moribund condition for several days afterwards. Such female ticks had probably completed about half of their parasitic life as adults, and had thus already commenced to develop some resistance at the time of treatment. Although the treatment failed to destroy them at once, they eventually died while still attached to the host, in some cases as long as a fortnight later.

The whole of the nymphs and larvæ on these animals were completely destroyed.

The cattle which were retained in the dip presented little difference when compared with those cattle which were allowed to swim right through.

Conclusion.—Increasing the length of the dipping vat within reasonable limits (or retaining the animal longer in the dipping fluid) does not produce any difference in the ultimate effect of the dipping fluid on the tick.

EXPERIMENT VI.—TO DETERMINE WHETHER ALTERATIONS IN THE PHYSICAL CHARACTER OF A DIPPING FLUID, SUCH AS MAY BE BROUGHT ABOUT BY PROLONGED USE, AFFECTS IN ANY WAY THE EFFICACY OF SUCH FLUID.

As a result of considerable field experience in the use of both clean and dirty dips, one of us (J.L.) has been led to regard the dirty dip with some suspicion. It has been noticed that the dip which has been in use for some considerable time, and which contains a large quantity of excrement, hair, dirt, &c., washed from the bodies of the cattle, has apparently allowed a considerably greater number of ticks to escape complete destruction than in the case of the clean, freshly charged dip. Theoretically, the arsenic content remaining the same, there should be little difference between the dirty and clean dipping fluids.

The dipping vat used by us had been cleaned out each year for several years and there was an accumulation of dirt, excrement, &c., piled at the side of the dip. It was decided to use this material by thoroughly mixing it with the dipping fluid.

The fluid used consisted of 6·2 lb. arsenic as As_2O_3 and 2·28 lb. as As_2O_5, 4 lb. caustic soda, 1½ gallon tar, and 2 lb. hard soap per 400 gallons.

Twenty-two head of cattle were used in this experiment. Two were set aside as controls, ten were passed through before the dirt, &c., was added, and ten afterwards. Before the second lot of animals was passed through, care was taken to see that the dirt, &c., was thoroughly distributed throughout the dipping fluid.

After treatment the cattle were allowed grazing under circumstances which precluded natural infestation, and all ticks as they reached maturity were collected and set aside for subsequent observation.

The observation was carried out in June, 1928. The results are set out in the following table (Table VI.) : —

TABLE VI.

Arsenic (As_2O_3) 6·2 lb., arsenic (As_2O_5) 2·28 lb., Stockholm tar 1½ gal., hard soap 2 lb. per 400 gallons.

June, 1928.

No. of Animal.	Type of Infestation.	Treatment.	Number of Fertile Ticks removed.			
			1st Week.	2nd Week.	3rd Week.	4th Week.
554	Light ..	Dipping fluid clear	38	3	4	Nil
555	Light ..		7	Nil	Nil	Nil
556	Moderate ..		Nil	Nil	Nil	Nil
557	Light ..		7	Nil	2	Nil
558	Heavy ..		8	1	1	Nil
559	Light ..		Nil	2	Nil	Nil
560	Light ..		4	1	Nil	Nil
561	Moderate ..		Nil	Nil	Nil	1
562	Heavy ..		12	Nil	Nil	Nil
563	Heavy ..		20	4	Nil	Nil
564	Heavy ..		Nil	Nil	Nil	·1
565	Light ..	Controls ..	858	4,111	2,236	118
566	Light ..		1,256	2,022	2,168	236
567	Heavy ..	Dipping fluid heavily charged with dirt, hair, &c.	Nil	Nil	Nil	Nil
568	Light ..		Nil	Nil	Nil	Nil
569	Heavy ..		Nil	Nil	Nil	Nil
570	Moderate ..		Nil	1	Nil	1
571	Light ..		Nil	Nil	1	Nil
572	Moderate ..		10	Nil	Nil	Nil
574	Light ..		6	Nil	Nil	Nil
575	Light ..		Nil	Nil	Nil	1
576	Moderate ..		Nil	Nil	Nil	4
577	Light ..		Nil	Nil	Nil	Nil

Difficulty was experienced in suppressing the growth of moulds in the containers, and it is possible that these interfered with the fertility of some ticks.

DISCUSSION.

Nearly all the survivors were obtained during the first two to four days after treatment, after which odd ticks were collected from most animals. It is impossible to draw any distinction between the two groups, and it is obvious that, where due allowance is made for the different degrees of infestation of the animals concerned, the efficacy of the dipping fluid was not interfered with by the addition of dirt, excrement, &c.

Conclusion.—So long as the arsenical content is not disturbed, the efficacy of a dipping fluid is not interfered with by the addition of dirt, &c.

EXPERIMENT VII.—TO DETERMINE WHETHER TWO TREATMENTS AT SHORT INTERVALS WITH ARSENICAL DIPPING FLUIDS WITH AND WITHOUT CERTAIN ADJUVANTS WILL DESTROY ALL TICKS ON INFESTED CATTLE.

Four dipping fluids were used:—

1. Arsenic (As_2O_3) and caustic soda;
2. Arsenic and caustic soda + $1\frac{1}{2}$ gallon tar and 2 lb. hard soap per 400 gallons of solution;
3. Arsenic and caustic soda + 3 gallons tar and 4 lb. hard soap per 400 gallons of solution;
4. A proprietary liquid concentrate widely used in Queensland.

All of these medicaments were tested at strengths of 6, 7, 8, and 9 lb. arsenic (As_2O_3) per 400 gallons of solution, and each strength was tested with intervals of three, five, seven, and ten days between applications.

The experiment therefore helps to throw light on the value of an emulsion made up of tar and soap; firstly, as to whether the "tickicide" value of the medicament is increased by the use of such emulsion, and, secondly, whether the emulsion produces any beneficial effect on the skin of the animal. Evidence is also produced on the question of whether any variation in the interval between treatments, other things being equal, affects the ultimate result.

The animals were removed from tick-infested country in small groups at a time, treated in the usual manner—that is, crush inspected, classified, numbered for identification purposes—and then immersed in the medicament concerned. They were allowed to stand about twenty minutes in the draining pens, then passed into the open field. One or two controls were set aside from each group of animals concerned.

No attempts were made to collect ticks between treatments, but observations showed that on many animals considerable numbers of ticks were reaching maturity during the first two or three days after the initial treatment. After the second treatment, however, inspection commenced at once, and was continued, except where otherwise stated, until the twenty-eighth day after removal from infested pasture. All ticks reaching maturity were removed and segregated for further observation.

The results are set out in the following series of tables:—

TABLE VIIA.

Arsenic 9 lb., caustic soda q.s., adjuvant nil per 400 gallons.

September 1927.

No. of Animal.	Type of Infestation.	Interval between Treatments.	Total Mature Females Collected.	Total Females Ovipositing.	Average Number of Eggs.	Average % of Eggs Hatching.	Longevity of Resultant Larvæ.
235	Moderate ..		11	4	500	70	68 days
236	Light ..		4	Nil	..	..	..
237	Very heavy ..	3 days	16	6	300	Nil	..
238	Heavy ..		22	6	300	Nil	..
239	Light ..		14	7	300	1	31 days
240	Very heavy ..		Nil	..	..	..	..
241	Light ..		4	Nil	..	..	..
242	Very heavy ..	5 days	Nil	..	..	..	..
243	Moderate ..		1	Nil	..	..	..
244	Moderate ..		Nil	..	..	..	..
245	Very heavy ..		Nil	..	..	..	..
246	Very heavy ..		Nil	..	..	..	..
247	Moderate ..	7 days	Nil	..	..	..	..
248	Very heavy ..		Nil	..	..	..	..
249	Light ..		1	Nil	..	..	..
250	Moderate ..		Nil	..	..	..	..
251	Heavy ..		Nil	..	..	..	..
252	Light ..	10 days	Nil	..	..	..	..
253	Heavy ..		2	1	400	5	17 days
254	Moderate ..		Nil	..	..	..	..
255	Moderate ..	Controls	4,165	Approximately 100 per cent. normal viable females.			
256	Moderate ..		3,757				

TABLE VIIB.

Arsenic 9 lb., caustic soda q.s., adjuvant 1½ gal. Stockholm tar, 2 lb. hard soap per 400 gallons.

October 1927.

No. of Animal.	Type of Infestation.	Interval between Treatments.	Total Mature Females Collected.	Total Females Ovipositing.	Average Number of Eggs.	Average % of Eggs Hatching.	Longevity of Resultant Larvæ.
259	Heavy ..		20	Nil	..	..	..
260	Heavy ..		16	Nil	..	..	..
261	Heavy ..	3 days	8	Nil	..	..	..
262	Very heavy ..		Nil	..	..	..	..
263	Very heavy ..		1	Nil	..	..	..
264	Light ..		Nil	..	..	..	..
265	Heavy ..		Nil	..	..	..	..
266	Moderate ..	5 days	Nil	..	..	..	..
267	Heavy ..		Nil	..	..	..	..
268	Moderate ..		Nil	..	..	..	..
269	Light ..		Nil	..	..	..	..
270	Heavy ..		Nil	..	..	..	..
271	Heavy ..	7 days	Nil	..	..	..	..
272	Moderate ..		Nil	..	..	..	..
273	Light ..		Nil	..	..	..	..
274	Very heavy ..		Nil	..	..	..	..
275	Light ..		Nil	..	..	..	..
276	Heavy ..	10 days	Nil	..	..	..	..
277	Light ..		Nil	..	..	..	..
278	Light ..		Nil	..	..	..	..
279	Light ..	Controls	1,172	Approximately 100 per cent. normal viable females.			
280	Light ..		1,564				

TABLE VIIc.

Arsenic 9 lb., caustic soda q.s., adjuvant 3 galls. Stockholm tar, 4 lb. hard soap per 400 gallons.

May 1928.

No. of Animal.	Type of Infestation.	Interval between Treatments.	Total Mature Females Collected.	Total Females Ovipositing.	Average Number of Eggs.	Average % of Eggs Hatching.	Longevity of resultant Larvæ.
467	Very heavy	3 days	57	Nil	..	..	..
468	Light ..		8	Nil	..	..	..
469	Heavy ..		19	Nil	..	..	..
470	Heavy ..		8	Nil	..	..	..
471	Heavy ..		9	1	200	Nil	..
472	Light ..	5 days	Nil	..	..	..	Larvæ still alive 50 days after hatching.
473	Very heavy		4	3	1,200	80	
474	Heavy ..		6	Nil	..	..	
475	Heavy ..		Nil	..	..	..	
476	Heavy ..		Nil	..	..	..	..
477	Heavy ..	7 days	Nil	..	..	..	..
478	Heavy ..		Nil	..	..	..	..
479	Heavy ..		1	1	2,000	40	40 days
480	Heavy ..		Nil	..	..	..	..
481	Heavy ..		Ni	..	..	..	..
482*	Heavy ..	10 days	61	40	1,100	40	..
483	Moderate ..		1	Nil	..	..	..
484	Heavy ..		Nil	..	..	..	..
485	Light ..		Nil	..	..	..	..
486	Heavy ..		Nil	..	..	..	..
487	Heavy ..	Controls	11,601	Approximately 100 per cent. normal viable females.			
488	Heavy ..		7,344				

* No. 482. A very long-haired animal. On the first day after the second treatment this animal yielded thirty engorged female adults, twenty-five of these oviposited an average of 1,000 eggs each, 30 per cent. of the resultant mass of eggs proving fertile; on the second day eight engorged females were removed, one of which oviposited approximately 2,000 eggs, but the fertility was very low, only odd eggs hatching; on the third day seven engorged females were removed, of which five oviposited an average of 1,500 eggs each, with 50 per cent. fertility; on the fourth day eight engorged females were recovered, seven of which oviposited 1,500 eggs each, with a 50 per cent. fertility; eight ticks altogether were removed on the fifth, sixth, and tenth days, of which two only oviposited, but all the eggs proved non-fertile. No engorged females developed on the animal after the tenth day following the second treatment. Some of the larvæ arising from these surviving females were alive and quite active fifty days after hatching.

TABLE VIId.

Arsenic 9 lb., adjuvant, emulsion contained in proprietary liquid concentrate per 400 gallons.

August 1927.

No. of Animal.	Type of Infestation.	Interval between Treatments.	Total Mature Females Collected.	Total Females Ovipositing.	Average Number of Eggs.	Average % of Eggs Hatching.	Longevity of Resultant Larvæ.
164	Heavy ..	3 days	5	Nil	..	..	..
165	Heavy ..		14	Nil	..	..	..
166	Heavy ..		14	Nil	..	..	..
167	Heavy ..		11	1	40	Nil	..
168	Light ..		1	1	20	Nil	..
169	Heavy ..	5 days	4	Nil	..	..	..
170	Heavy ..		Nil	..	..	..	..
171	Heavy ..		Nil	..	..	..	..
172	Moderate ..		Nil	..	..	..	..
173	Moderate ..		1	Nil	..	..	..
174	Very heavy ..	7 days	2	Nil	..	..	..
175	Heavy ..		Nil	..	..	..	..
176	Very heavy ..		Nil	..	..	..	..
177	Light ..		1	Nil	..	..	..
178	Light ..		Nil	..	..	..	..
179	Light ..	10 days	Nil	..	..	..	..
180	Light ..		Nil	..	..	..	..
181	Heavy ..		Nil	..	..	..	..
182	Heavy ..		Nil	..	..	..	..
183	Moderate ..		Nil	..	..	..	..
184	Very heavy ..	Controls	5,849	engorged females removed first week after stalling.			
185	Heavy ..		3,849	engorged females removed 14 days after stalling.			

Approximately 100 per cent. of engorged females from controls normal viable females.

No counts made of ticks maturing on 184 after seventh day, nor on 185 after fifteenth day, although both animals still carried some thousands of immature ticks.

TABLE VIIe.

Arsenic 8 lb., caustic soda q.s., adjuvant nil, per 400 gallons.

August 1927.

No. of Animal.	Type of Infestation.	Interval between Treatments.	Total Mature Females Collected.	Total Females Ovipositing.	Average Number of Eggs.	Average % of Eggs Hatching.	Longevity of Resultant Larvæ.
218	Heavy ..	3 days	5	Nil	..	..	..
219	Very heavy ..		1	Nil	..	..	..
220	Heavy ..		2	Nil	..	..	..
221	Very heavy ..		Nil	..	..	..	..
222	Heavy ..	5 days	Nil	..	..	..	..
223	Heavy ..		Nil	..	..	..	..
224	Heavy ..		6	1	200	Nil	..
225	Very heavy ..		Nil	..	..	..	..
226	Very heavy ..	7 days	Nil	..	..	..	..
227	Heavy ..		Nil	..	..	..	..
228	Moderate ..		Nil	..	..	..	..
229	Moderate ..		Nil	..	..	..	..
230	Light ..	10 days	Nil	..	..	..	..
231	Heavy ..		Nil	..	..	..	..
232	Heavy ..		Nil	..	..	..	..
233	Heavy ..		Nil	..	..	..	..
*234	Heavy ..	Control ..	5,505	engorged females removed during the first 10 days of stalling, after which no further counts were made although the animal still carried some thousands of immature ticks.			

* See also Table VIIi. and Table VIIm.

TABLE VIIf.

Arsenic 8 lb., caustic soda q.s., adjuvant 1½ gal. Stockholm tar, 2 lb. hard soap per 400 gallons.

November 1927.

No. of Animal.	Tpye of Infestation	Interval between Treatments.	Total Mature Females Collected.	Total Females Ovipositing.	Average Number of Eggs.	Average % of Eggs Hatching.	Longevity of Resultant Larvæ.
296	Very heavy ..	3 days	41	7	150	Nil	..
297	Very heavy ..	3 days	20	7	150	Nil	..
298	Very heavy ..	3 days	19	2	100	Nil	..
299	Moderate ..	3 days	3	0	Nil	..	..
300	Very heavy ..	3 days	12	3	150	Nil	..
301	Very heavy ..	5 days	Nil	Nil	..	..	..
302	Moderate ..	5 days	Nil	Nil	..	..	..
303	Very heavy ..	5 days	14	2	150	Nil	..
304	Very heavy ..	5 days	2	Nil	..	..	..
305	Very heavy ..	5 days	1	Nil	..	..	..
306	Very heavy ..	7 days	1	Nil	..	..	..
307	Very heavy ..	7 days	2	Nil	..	..	..
308	Very heavy ..	7 days	2	2	50	Nil	..
309	Very heavy ..	7 days	Nil	..	..	..	..
310	Very heavy ..	7 days	Nil	..	..	..	..
311	Very heavy ..	10 days	2	Nil	..	..	..
312	Heavy ..	10 days	2	2	75	Nil	..
313	Heavy ..	10 days	Nil	..	..	..	..
314	Heavy ..	10 days	Nil	..	..	..	..
315	Heavy ..	10 days	Nil	..	..	..	..
318	Moderate ..	Controls	3,561	Approximately 100 per cent. normal viable females.			
319	Moderate ..	Controls	3,181				

TABLE VIIg.

Arsenic 8 lb., caustic soda q.s., adjuvant 3 galls. Stockholm tar, 4 lb. hard soap per 400 gallons.

April 1928.

No. of Animal.	Type of Infestation.	Interval between Treatments.	Number of Engorged Females.	Number of Females Ovipositing.	Average Number of Eggs.	Average % of Eggs Hatching.	Longevity of Resultant Larvæ.
452	Moderate ..	3 days	Nil	..	..	..	..
453	Moderate ..	3 days	Nil	..	..	..	..
454	Heavy ..	3 days	Nil	..	..	..	..
455	Light ..	3 days	Nil	..	..	..	..
456	Heavy ..	5 days	Nil	..	..	..	..
457	Moderate ..	5 days	Nil	..	..	..	..
458	Heavy ..	5 days	Nil	..	..	..	..
459	Heavy ..	7 days	Nil	..	..	..	..
460	Moderate ..	7 days	Nil	..	..	..	..
461	Light ..	7 days	Nil	..	..	..	..
462	Light ..	10 days	Nil	..	..	..	..
463	Moderate ..	10 days	Nil	..	..	..	..
464	Moderate ..	10 days	Nil	..	..	..	..
465	Moderate ..	Controls	6,579	Approximately 100 per cent. normal viable females.			
466	Moderate ..	Controls	3,589				

Examinations completed on twenty-third day after removal from tick-infested country. From the fourteenth to the twenty-third day ten consecutive daily examinations had failed to locate one tick on any one animal.

Table VIIh.

Arsenic 8 lb., caustic soda q.s., adjuvant emulsion contained in proprietary liquid concentrate per 400 gallons.

May 1927.

No. of Animal.	Type of Infestation.	Interval between Treatments.	Number of Engorged Females.	Number of Female Ovipositing.	Average Number of Eggs.	Average % of Eggs Hatching.	Longevity of Resultant Larvæ.
58	Moderate ..		17	1	2,000	90	42 days
59	Light ..		9	Nil	..	..	..
60	Heavy ..	3 days	9	1	500	Nil	..
61	Moderate ..		4	Nil	..	..	..
144A	Heavy ..		19	Nil	..	..	..
145A	Heavy ..		16	1	100	Nil	..
132	Very heavy ..		4	1	200	Nil	..
133	Very heavy ..		6	3	1,000	1	9 days
134	Very heavy ..	5 days	10	Nil	..	..	..
135	Very heavy ..		2	Nil	..	..	..
136	Very heavy ..		6	1	200	Nil	..
72	Moderate ..		Nil	..	..	..	..
73	Light ..		Nil	..	..	..	..
74	Moderate ..	7 days	Nil	..	..	..	..
75	Light ..		Nil	..	..	..	..
76	Light ..		Nil	..	..	..	..
137	Very heavy ..		27	12	1,500	30	19 days
138	Very heavy ..		2	2	1,200	Nil	..
139	Very heavy ..	10 days	Nil	..	..	..	..
140	Very heavy ..		1	Nil	..	..	..
141	Very heavy ..		30	18	800	Nil	..
*92	Light ..	Controls	2,545				
93	Moderate ..	58-61	3,019	Approximately 100 per cent. viable ticks.			
94	Moderate ..	72-76	2,906				
142	Very heavy ..	Controls	5,306	(six days only) approximately 100 per cent. viable ticks.			
143	Very heavy ..	144A,	4,621				
		132-141					

No counts made on 142 and 143 after sixth day, although these animals still carried some thousands of immature ticks.

* See Table VIIl. and Table VIIp.

Table VIIi.

Arsenic 7 lb., caustic soda q.s., adjuvant nil per 400 gallons.

August 1927.

No. of Animal.	Type of Infestation.	Interval between Treatments.	Number of Engorged Females.	Number of Females Ovipositing.	Average Number of Eggs.	Average % of Eggs Hatching.	Longevity of Resultant Larvæ.
202	Heavy ..		6	Nil	..	..	..
203	Heavy ..	3 days	Nil	..	..	..	..
204	Light ..		Nil	..	..	..	..
205	Moderate ..		17	2	1,500	Nil	..
206	Moderate ..		Nil	..	..	..	..
207	Light ..	5 days	Nil	..	..	..	..
208	Heavy ..		8	1	300	Nil	..
209	Light ..		Nil	..	..	..	..
210	Heavy ..		Nil	..	..	..	..
211	Very heavy ..	7 days	Nil	..	..	..	..
212	Heavy ..		Nil	..	..	..	..
213	Very heavy ..		Nil	..	..	..	..
214	Light ..		Nil	..	..	..	..
215	Heavy ..	10 days	Nil	..	..	..	..
216	Heavy ..		Nil	..	..	..	..
217	Heavy ..		Nil	..	..	..	..
*234	Heavy ..	Control ..	5,505	engorged females removed during first ten days of stalling, after which no further counts were made, although the animal still carried many thousands of immature ticks.			

* See also Tables VIIe. and VIIm.

TABLE VIIJ.

Arsenic 7 lb., caustic soda q.s., adjuvant $1\frac{1}{2}$ gal. Stockholm tar, 2 lb. hard soap per 400 gallons.

December 1927.

No. of Animal.	Type of Infestation.	Interval between Treatments.	Number of Engorged Females.	Number of Females Ovipositing.	Average Number of Eggs.	Average % of Eggs Hatching.	Longevity of Resultant Larvæ.
338	Very heavy ..	3 days	2	2	400	50	17 days
339	Light ..		Nil	..	..	..	..
340	Very heavy ..		Nil	..	..	..	..
341	Light ..		Nil	..	..	..	..
342	Moderate ..		1	1	50	Nil	..
343	Light ..	5 days	Nil	..	..	..	..
344	Light ..		Nil	..	..	..	..
345	Light ..		Nil	..	..	..	..
346	Light ..		Nil	..	..	..	..
347	Light ..		Nil	..	..	..	..
348	Heavy ..	7 days	Nil	..	..	..	..
349	Moderate ..		Nil	..	..	..	..
350	Light ..		Nil	..	..	..	..
351	Light ..		1	1	400	20	39 days
352	Heavy ..		2	2	200	10	43 days
353	Light ..	10 days	Nil	..	..	..	..
354	Light ..		Nil	..	..	..	..
355	Light ..		Nil	..	..	..	..
356	Light ..		Nil	..	..	..	..
357	Light ..		1	1	200	90	49 days
358	Light ..	Controls	1,832	Approximately 100 per cent. viable ticks.			
359	Light ..		666				

NOTE.—The above cattle were not all heavily infested with ticks in all stages. They mostly carried heavy infestations of young ticks up to and including engorged nymphs. Several, however, carried ticks in all stages.

No. 359 was specially selected as a control, as it appeared to be and probably was the most lightly infested animal in this group.

TABLE VIIK.

Arsenic 7 lb., caustic soda q.s., adjuvant 3 galls. Stockholm tar, 4 lb. hard soap per 400 gallons.

March 1928.

No. of Animal.	Type of Infestation.	Interval between Treatments.	Number of Engorged Females.	Number of Females Ovipositing.	Average Number of Eggs.	Average % of Eggs Hatching.	Longevity of Resultant Larvæ.
420	Moderate ..	3 days	1	Nil	..	..	..
421	Heavy ..		1	Nil	..	..	.
422	Heavy ..		4	1	800	Nil	..
423	Moderate ..		5	Nil	..	..	..
424	Moderate ..		3	2	1,000	Nil	..
425	Moderate ..	5 days	4	2	1,000	20	47 days
426	Moderate ..		Nil	..	..	..	..
427	Heavy ..		Nil	..	..	..	..
428	Moderate ..		1	Nil	..	..	..
429	Heavy ..		1	Nil	..	..	..
430	Light ..	7 days	5	5	2,000	75	43 days
431	Moderate ..		6	4	1,500	Few only	Not determined
432	Light ..		Nil	..	..	..	..
433	Heavy ..		4	4	1,500	20	49 days
434	Heavy ..		42	35	1,500	70	47 days
435	Heavy ..	10 days	Nil	..	..	..	..
436	Heavy ..		Nil	..	..	..	..
437	Moderate ..		2	2	1,000	Nil	..
438	Heavy ..		Nil	..	..	..	..
439	Light ..		Nil	..	..	..	..
440	Moderate ..	Controls	8,177	Approximately 100 per cent. normal viable ticks.			
441	Moderate ..		6,468				

TABLE VIIL.

Arsenic 7 lb., caustic soda q.s., adjuvant, emulsion contained in proprietary liquid concentrate, per 400 gallons.

May 1927.

No. of Animal.	Type of Infestation.	Interval between Treatments.	Number of Engorged Females.	Number of Females Ovipositing.	Average Number of Eggs.	Average % of Eggs Hatching.	Longevity of Resultant Larvæ.
54	Moderate ..	3 days	6	Nil	..	..	..
55	Light ..	3 days	3	Nil	..	..	..
56	Very heavy ..	3 days	18	2	600	50	51 days
57	Moderate ..	3 days	18	2	1,100	90	35 days
122	Very heavy ..	5 days	14	3	1,200	Nil	..
123	Very heavy ..	5 days	8	6	500	Nil	..
124	Very heavy ..	5 days	Nil	..	..	..	..
125	Very heavy ..	5 days	5	2	100	Nil	..
126	Very heavy ..	5 days	3	Nil	..	..	..
67	Moderate ..	7 days	3	1	200	Nil	..
68	Light ..	7 days	Nil	..	..	..	..
69	Moderate ..	7 days	Nil	..	..	..	..
70	Moderate ..	7 days	3	1	1,500	90	29 days
71	Heavy ..	7 days	Nil	..	..	..	..
127	Very heavy ..	10 days	5	4	1,200	20	31 days
128	Very heavy ..	10 days	2	Nil	..	..	..
129	Very heavy ..	10 days	3	2	1,500	Nil	..
130	Very heavy ..	10 days	3	1	2,000	Nil	..
131	Very heavy ..	10 days	3	2	1,500	Nil	..
*92	Light ..	Controls 54-57 67-71	2,545	Approximately 100 per cent. normal viable ticks.			
93	Moderate ..	Controls 54-57 67-71	3,019	Approximately 100 per cent. normal viable ticks.			
94	Moderate ..	Controls 54-57 67-71	2,906	Approximately 100 per cent. normal viable ticks.			
*142	Very heavy ..	Controls 122-131	5,306	(first six days only) approximately 100 per cent. normal viable ticks.			
143	Very heavy ..	Controls 122-131	4,621	(first six days only) approximately 100 per cent. normal viable ticks.			

No counts made on 142 and 143 after sixth day.

* See also Tables VIIH. and VIIP.

TABLE VIIM.

Arsenic 6 lb., caustic soda q.s., adjuvant nil, per 400 gallons.

August 1927.

No. of Animal.	Type of Infestation.	Interval between Treatments.	Total Engorged Females.	Total Females Ovipositing.	Average Number of Eggs.	Average % of Eggs Hatching.	Longevity of Resultant Larvæ.
186	Heavy ..	3 days	14	1	30	Nil	..
187	Heavy ..	3 days	1	Nil	..	..	..
188	Light ..	3 days	Nil	..	..	..	..
189	Heavy ..	3 days	Nil	..	..	..	..
190	Heavy ..	5 days	5	Nil	..	..	..
191	Very heavy ..	5 days	Nil	..	..	..	..
192	Light ..	5 days	Nil	..	..	..	..
193	Heavy ..	5 days	Nil	..	..	..	..
194	Heavy ..	7 days	Nil	..	..	..	..
195	Very heavy ..	7 days	Nil	..	..	..	..
196	Very heavy ..	7 days	Nil	..	..	..	..
197	Light ..	7 days	Nil	..	..	..	..
198	Heavy ..	10 days	Nil	..	..	..	..
199	Very heavy ..	10 days	Nil	..	..	..	..
200	Light ..	10 days	Nil	..	..	..	..
201	Heavy ..	10 days	9	Nil	..	..	..
*234	Heavy ..	Control ..	5,505	engorged females removed first ten days of stalling, after which no further counts were made, although the animal still carried many thousands of immature ticks. Approximately 100 per cent. normal viable females.			

* This animal also acted as control for those animals shown in Tables VIIE. and VIII.

TABLE VIIN.

Arsenic 6 lb., caustic soda q.s., adjuvants $1\frac{1}{2}$ gal. Stockholm tar, 2 lb. hard soap per 400 gallons.

January 1928.

No. of Animal.	Type of Infestation.	Interval between Treatments.	Total Engorged Females.	Total Females Ovipositing.	Average Number of Eggs.	Average % of Eggs Hatching.	Longevity of Resultant Larvæ.
360	Very heavy ..	3 days	8	Nil	..	..	..
361	Heavy ..		23	Nil	..	..	..
362	Very heavy ..		12	4	400	Nil	..
363	Very heavy ..		7	3	300	Odd ones	Not determined
364	Moderate ..		4	Nil	..	..	..
365	Light ..	5 days	Nil	..	..	..	..
366	Light ..		Nil	..	..	..	..
367	Moderate ..		Nil	..	..	..	..
368	Heavy ..		Nil	..	..	..	..
369	Heavy ..		Nil	..	..	..	..
370	Very heavy ..	7 days	Nil	..	..	..	..
371	Very heavy ..		Nil	..	..	..	..
372	Moderate ..		Nil	..	..	..	..
373	Heavy ..		Nil	..	..	..	..
374	Heavy ..		1	Nil	..	..	..
375	Moderate ..	11 days (owing to heavy rain)	Nil	..	..	..	..
376	Very heavy ..		1	Nil	..	..	..
377	Heavy ..		Nil	..	..	..	..
378	Heavy ..		Nil	..	..	..	..
379	Heavy ..		Nil	..	..	..	..
380	Heavy ..	Controls	10,948	Approximately 100 per cent. normal viable ticks.			
381	Very heavy ..		22,768				

No counts made on controls after eighteenth day, although both animals apparently still carried a few thousand ticks. No. 381 was the only animal classified as a "very heavy" infestation, which was used as a control, and from which anything like an approximate estimate of the total number of ticks carried by such an animal was obtained. During the first eighteen days of stalling nearly 23,000 engorged female adults were collected. The condition of this animal was typical of many others classed as "very heavy" infestations; further there is little doubt that many of the "heavy" infestations would have yielded a number of ticks not far short of the above total, because the tendency was to classify the animals in the lower rather than in the higher category.

TABLE VIIo.

Arsenic 6 lb., caustic soda q.s., adjuvant 3 galls. Stockholm tar, 4 lb. hard soap per 400 gallons.

January 1928.

No. of Animal.	Type of Infestation.	Interval between Treatments.	Total Engorged Females.	Total Females Oviipositing.	Average Number of Eggs.	Average % of Eggs Hatching.	Longevity of Resultant Larvæ.
397	Moderate ..	3 days	Nil	..	..	..	..
398	Light ..		Nil	..	..	..	..
399	Light ..		Nil	..	..	..	..
400	Light ..		Nil	..	..	..	..
401	Light ..		Nil	..	..	..	..
402	Light ..	5 days	Nil	..	..	..	..
403	Light ..		Nil	..	..	..	..
404	Light ..		Nil	..	..	..	..
405	Moderate ..		Nil	..	..	..	..
406	Heavy ..		Nil	..	..	..	..
407	Very heavy ..	7 days	Nil	..	..	..	..
408	Light ..		Nil	..	..	..	..
409	Very heavy ..		Nil	..	..	..	..
410	Light ..		Nil	..	..	..	..
411	Moderate ..		Nil	..	..	..	..
412	Very heavy ..	10 days	Nil	..	..	..	..
413	Light ..		Nil	..	..	..	..
414	Very heavy ..		Nil	..	..	..	..
415	Light ..		Nil	..	..	..	..
416	Heavy ..		Nil	..	..	..	..
417	Light ..	Control ..	1,241	Approximately 100 per cent. normal viable ticks.			

No. 417 (control) was specially selected as being apparently the most lightly infested animal in the group.

TABLE VIIp.

Arsenic 6 lb., caustic soda q.s., adjuvant emulsion contained in proprietary liquid concentrate, per 400 gallons.

May 1927.

No. of Animal.	Type of Infestation.	Interval between Treatments.	Total Engorged Females.	Total Females Ovipositing.	Average Number of Eggs.	Average % of Eggs Hatching.	Longevity of Resultant Larvæ.
50	Light ..	3 days	4	Nil	..	..	..
51	Light ..		4	Nil	..	..	..
52	Heavy ..		9	2	300	90	Not determined
53	Heavy ..		5	Nil	..	..	..
112	Very heavy ..	5 days	1	1	2,500	50	28 days
113	Very heavy ..		3	Nil	..	..	..
114	Very heavy ..		10	Nil	..	..	..
115	Very heavy ..		1	1	1,500	Nil	..
116	Very heavy ..		2	1	1,000	Nil	..
62	Moderate ..	7 days	4	1	2,000	90	43 days
63	Heavy ..		2	Nil	..	..	..
64	Very heavy ..		Nil	..	..	..	..
65	Very heavy ..		4	4	500	80	35 days
66	Moderate ..		5	3	700	Nil	..
117	Very heavy ..	10 days	3	3	2,000	Nil	..
118	Very heavy ..		5	3	1,200	Nil	..
119	Very heavy ..		6	3	350	Nil	..
120	Very heavy ..		45	30	1,200	20	3 days
92	Light ..	Controls 50-53 62-66	2.545	Approximately 100 per cent. normal viable ticks.			
93	Moderate ..		3,019				
94	Moderate ..		2,906				
*142	Heavy ..	Controls 112-120	5,306	(six days only), approximately 100 per cent. normal viable ticks.			
143	Heavy ..		4,621				

* See also Tables VIIH. and VIIL.

Discussion.

In order to simplify the sixteen different tables set out under the experiment under discussion, we have tabulated in a brief and concise manner the whole of the results in the simple table below:—

Table VIIq.

Adjuvants per 400 gallons.	Arsenic as As_2O_3 per 400 galls. 6lb.				Arsenic as As_2O_3 per 400 galls. 7lb.				Arsenic as As_2O_3 per 400 galls. 8lb.				Arsenic as As_2O_3 per 400 galls. 9lb.			
	Days between Treatment.															
	3	5	7	10	3	5	7	10	3	5	7	10	3	5	7	10
Nil	†	†	†	†	†	†	†	†	†	†	†	†	–	†	†	–
1½ gal. Stockholm tar and 2 lb. hard soap	–	†	†	†	–	†	–	–	†	†	†	†	†	†	†	†
3 galls. Stockholm tar and 4 lb. hard soap	†	†	†	†	†	–	–	†	†	†	†	†	†	–	–	–
Emulsion contained in certain proprietary medicament	–	–	–	–	–	†	–	–	–	–	†	–	†	†	†	†

† means all ticks immediately destroyed or survivors failed to oviposit fertile eggs

– means some survivors ovipositing fertile eggs, or treatment was less than 100 per cent. effective.

1. *The Value of Emulsion.*

(*a*) *Increasing the "tickicide" value of the dipping fluid.*—One of the emulsions employed, consisting of Stockholm tar and ordinary hard soap, is almost identical with that prescribed by the New South Wales Stock Department and one of those prescribed by the Queensland Stock Department, except that such emulsion was used and tested by us in considerably greater proportions than that recommended by either department.

The Queensland official dip A (see Regulations under Stock Diseases Act) contains ½ gallon Stockholm tar and 4 lb. tallow or oil, the latter being emulsified by means of caustic soda.

The New South Wales official dipping fluid contains ½-1 gallon of tar and 2 lb. hard soap, while washing soda is used in place of caustic soda to bring about solution of the arsenic and to emulsify the adjuvants used.

In all of those countries in which the dipping of cattle for tick destruction is carried out extensively, emulsions are as a rule considered necessary to bring about maximum effectivity, and they are usually included in official dipping fluids. There seem to be some theoretical reasons why they should be added to such fluids. But in order to warrant the inclusion of an adjuvant like Stockholm tar, it would be necessary to show that such an ingredient was of more than minor importance, because even the addition of the small quantities prescribed in the official formulæ adds considerably to the cost of the medicament.

Brünnich and Smith[1,2] state that, when tallow or oil soaps and Stockholm tar are incorporated with an arsenical dipping solution extra efficiency is obtained, with the result that these or similar adjuvants are now universally used as ingredients in cattle-dipping fluids. They agree as to the absolute necessity of these substances if maximum tick-destroying effects are desired. These observers also consider that the extra efficiency is brought about as a result of a lower surface tension found in a fluid containing emulsion, this physical factor admitting of a more thorough wetting of the skin of the host and its parasite. A series of experiments were carried out by these workers, which showed that the oleic acid soaps had a higher wetting power than the ordinary stearic acid soaps of tallow, and they therefore recommend the use of the former soaps in preference to tallow soaps in the preparation of dipping fluids. "Stockholm tar soap" and resin were regarded as being of considerable efficacy. Phenolic agents they do not regard as being of any value as emulsifying agents. Increase of the amount of alkali in the Government dip formula they do not consider advisable under ordinary circumstances. They showed also, that the use of hard water leads to a marked diminution in the wetting power of a dip containing fatty acid soaps, owing to the precipitating action of the calcium and magnesium salts.

These two observers also carried out some experiments on the use of bone-oil as an adjuvant in arsenical dipping fluids, and concluded that it could be used as a substitute for tar and soap. It was preferable in some respects as it was less expensive.

Bulletin 1057 of the U.S.A. Department of Agriculture recommends the use of pine tar as an adjuvant in the preparation of arsenical dipping fluids. It is there stated that a plain solution of sodium arsenite does not make an entirely satisfactory dip and the addition of pine tar possibly "increases the wetting or spreading power of the dip bath, which probably results in better penetration and effectiveness against ticks and less risk of blistering."

Cooper and Laws[5] observe that an aqueous solution of sodium arsenite must be used in considerably greater concentration than when used in conjunction with an emulsion of soap and oil in order to bring about the same destructive effect on the tick. They found that a solution of sodium arsenite containing ·153 per cent. As_2O_3 plus emulsion was as efficacious as a solution containing ·225 per cent. As_2O_3 without emulsion. These authors therefore regard the use of emulsions in cattle-dipping fluids as being of very great importance.

Watkins Pitchford[7] carried out a series of observations in Natal on the effect of treating tick-infested cattle with arsenical dipping fluids. He showed that cattle could be treated at three-day intervals over long periods with an arsenical solution containing adjuvants such as soft soap and paraffin, and of sufficient strength to destroy the tick but yet produce no untoward effect on the animal host. The use of the three-day dip was recommended where East Coast fever had appeared on a farm, and where it was essential that all ticks should be destroyed before they had completed their engorgement and dropped from the host. As the shortest period occupied by the tick in any one of its parasitic stages was approximately three days, treatments were spaced at intervals of not longer than seventy-two hours. The arsenical strength of the three-day dip was approximately 2 lb. of arsenic (As_2O_3) per 400 gallons of solution, and treatment with this fluid was supplemented by hand dressing of certain parts of the body, such as inside the ears, the under surface of the butt of the tail, and the end of the tail, or brush, these three points being seats of predilection of the tick. The nymphal tick frequently entered the ear passage and penetrated as far as the tymphanic membrane and was often protected by the waxy secretion from the ear-glands, while the adults found under the tail and in the brush often formed dense aggregations of parasites in the form of a thatch.

The same observer recommended the use of a five-day dip which contained approximately double the quantity of arsenic used in the three-day dip. He found that this solution, together with an emulsion of paraffin and soap, could be used over long periods without detriment to the cattle treated, while it destroyed large numbers of parasites and reduced the ticks on the pasture to a very small minimum.

This worker concluded that the use of paraffin and soap increased to a certain extent the tick-destroying powers of the arsenic.

Cohen[3] states that the use of emulsion is not essential provided the wetting is thorough, but adds that as this cannot be ensured under ordinary field conditions he recommends its use.

Jack,[11] quoting Theiler, states that many farmers in South Africa use an aqueous solution of sodium arsenite and do not regard the extra expense involved by adding soft soap and paraffin to the mixture as being warranted.

Much of the work conducted in investigating the use of cattle dips has been performed in countries like South Africa, where the economic importance of the tick is considerably greater than in Australia. Moreover, the conditions in the two countries are entirely different. In South Africa efforts at eradication are directed against such ticks as *Rhipicephalus appendiculatus*, the brown tick, which is an interrupted feeder spending only a few days at a time as a parasite; while in Australia *Boophilus australis*, the common cattle tick, is a continuous feeder spending at least twenty days on its host. Hence a system of treatment which might eradicate a tick like *Boophilus australis* would be useless against a tick like *Rhipicephalus appendiculatus*. Continuous feeders like *Boophilus decoloratus*—in South Africa a tick closely allied to the *Boophilus australis*—are not considered to be of such economic importance as the interrupted feeders which convey such diseases as East Coast fever, and any system of treatment which will eradicate the interrupted feeder will also account for the continuous feeder. It is because of the importance of the interrupted feeder in South Africa that so much work has been done with the short-period dipping fluid of high dilution, and why Watkins Pitchford and others attempted experiments designed to discover some substance, other than arsenic, not poisonous to the animal host but which increased the tick-destroying power of the arsenical fluid.

Although, therefore, there seems to be a general opinion on the question of whether an emulsion should be added to dipping fluids, so far as we know, no comparative experiments extensive enough to warrant clear-cut and definite conclusions as to the value of emulsions—taking into consideration their cost and the ease with which they can be incorporated in the arsenical solution—in increasing the "tickicide" value of cattle-dipping fluids have ever been performed in Australia.

If we now examine the table setting out the results of the animals treated in this experiment, it is fairly clear that the amount of emulsion used bore no relationship to the result. In the dipping solution containing 1½ gallon of tar per 400 gallons solution, the whole of the ticks were destroyed at strengths of 8 and 9 lb. arsenic, but failed to destroy at 6 and 7 lb. arsenic. When the amount of emulsion was doubled the 6 and 8 lb. dips destroyed all ticks, but the solution failed at 7 lb. and again at 9 lb. On the other hand, the dipping fluid consisting of an aqueous solution of sodium arsenite destroyed all ticks at 6, 7, and 8 lb., but failed to destroy at 9 lb., a seeming paradox. The proprietary medicament failed to destroy at 6, 7, and 8 lb. per 400 gallons, but destroyed all ticks when the amount of arsenic, plus a proportionate amount of emulsion, was raised to 9 lb.

Actually the evidence shows that, of all these groups of cattle treated in a solution of sodium arsenite without emulsion, a greater number of groups remained entirely clean after treatment than in the case of those groups of cattle treated in dipping solutions containing emulsions. This does not indicate that the value of the medicament as a tick-destroying agent is *decreased* by the addition of emulsion, but it does indicate that a solution of sodium arsenite without the addition of emulsion or adjuvant of any kind is a powerful tick-destroying agent so far as *Boophilus australis* is concerned, and compares very favourably with those dipping fluids tested which contained emulsions, in some cases in considerable quantities. So far as our own observations go they point to the conclusion at least that under field conditions the omission of the emulsion does not decrease in any way the tick-destroying powers of the dipping fluids tested.

(*b*) *As an Emollient.*—Besides increasing the "tickicide" value of the dipping fluid, some observers regard the inclusion of emulsions as a necessary factor in preventing scalding and cracking of the skin.

Brünnich and Smith are of the opinion that emulsions have a decidedly beneficial and emollient effect while aqueous solutions of sodium arsenite have at times a severe local scalding action.

Watkins Pitchford regarded the use of paraffin and soft soap as an important factor in preventing cracking and scalding of the skin, and showed that animals could withstand the short-interval treatments without detriment over longer periods when emulsions were added than when treated with an aqueous solution of sodium arsenite.

The short-interval treatment, as we previously stated, so necessary in South Africa, is responsible for the cracking and scalding of the skin, whereas in Australia short-interval treatment is not required and the use of an ingredient which would prevent this untoward feature is not demanded to the same extent.

During our experiments we have made careful note as to the effect of the dipping fluid on the skin of the animals, and it was impossible to distinguish between the effects of the dipping fluids containing emulsion and those containing no emulsion. Slight cracking of the skin only occurred in an odd animal even with the 9-lb. dips in those cattle undergoing two treatements at seventy-two hour intervals. A reference to the tables will show that some of the cattle were treated in the stronger solutions of arsenic (8 and 9 lb.) during the summer months (October and November), or over a period when the weather conditions in North Queensland are very hot and oppressive.

It has always been difficult for us to conceive how the employment of an emulsion made up of tar and soap in such small quantities as laid down in the official formulæ can have any beneficial or emollient effect on the skin of the host.

Considering that the Queensland official formula "A" contains $\frac{1}{2}$ gallon tar to 400 gallons of solution, and that each animal takes out of a dip about 1 gallon of fluid (or $\frac{1}{800}$ gallon of tar) which is spread over the complete surface of the skin and hair, one has difficulty in understanding how such an extremely small quantity of tar and soap can be credited with beneficial properties.

It is quite true that many heavily infested animals show a marked improvement in the general condition of the cutaneous tissues within a few days of treatment, but this benefit is undoubtedly due to the destruction of the tick and the healing of the tick sores.

One of us (J.L.), after considerable field observation following the use of dipping fluids of standard strength, has been led to the belief that extensive cracking of the skin* only occurs where animals are driven considerable distances immediately or soon after treatment (next day), and this will occur even after a single treatment and irrespective of whether the particular dipping fluid contained emulsion or not. The condition is considerably aggravated during hot weather, particularly if the cattle are wild and difficult to hold.

Where cattle are kept quiet and unmolested, as in our own experiments, two treatments only a few days apart even in summer, under

* The same feature may be seen in cattle entrained and travelled over long distances immediately or soon after treatment.

North Queensland conditions, produced little, if any, effect on the skin of the animals, irrespective of whether emulsion was or was not added to the dipping fluid.

2. *Arsenical Strength of Dipping Fluid.*

A comparison of the four different dips tested (that is, different in the matter of arsenical strength, viz., 6, 7, 8, and 9 lb. arsenic, as As_2O_3, per 400 gallons) shows that there was no great difference between each group. In no case did any one of these four different dipping fluids destroy all ticks on all animals treated with two applications of the medicament.

The dipping fluid containing 6 lb. arsenic per 400 gallons failed on one occasion when the emulsion consisted of 1½ gallon tar and 2 lb. hard soap per 400 gallons, and on all four occasions when the proprietary mixture was tested. The 7-lb. dip failed three times when the emulsion consisted of 1½ gallon tar and 2 lb. hard soap, twice when the solution contained double this quantity of adjuvant, and three times with the proprietary dip. At 8 lb. all dips were effective except the proprietary mixture, which failed three times; whilst at 9 lb. two dips failed, viz., the one containing no adjuvant and that containing the maximum amount of tar and soap. The other two dips tested at 9 lb., viz., that containing the proprietary mixture and that containing the smaller quantity of tar and soap (1½ gallon tar and 2 lb. soap), both proved effective in destroying 100 per cent. of the ticks on the animals treated.

If we again examine the various tables which set out details concerning the degree of infestation of the cattle concerned, we shall notice that compared with the controls the actual number of ticks which were subject to treatment by any one of these four different dips tested was at least very many thousands. When we further examine the columns showing the actual number of ticks which survived treatment, we find that rarely did the number of such survivors exceed four or five. Even where a considerably greater number of survivors were found ovipositing (such as No. 120, Table VIIP.) it will be noted that the percentage of fertile eggs was fairly low, thus showing that probably only a small percentage of surviving females contributed fertile eggs.

On the whole it can be said that, although all four dips were highly efficient, there is nothing like the margin one might expect between two treatments in a dip containing 6 lb. arsenic per 400 gallons and one containing 9 lb. of the same ingredient in an equal quantity of fluid. The former occasionally allows not more than an odd tick to escape even on the most grossly infested cattle, and the latter may apparently do likewise under some circumstances.

3. *Interval between Treatments.*

As shown in the tables, the intervals allowed were 3, 5, 7, and 10 days. Practically no difference was noted between the various groups. Odd ticks appear to escape irrespective of the interval allowed. It will be noted that a greater number of engorged ticks were usually removed where the treatments were spaced at intervals of three days, but the number of such survivors contributing fertile eggs was in reality no greater than where the intervals were larger.

4. *Portions of the Body on which Survivors were Found.*

If we examine the subsequent history of animals which received one treatment in an arsenical dipping fluid (as Animals Nos. 511, 512, 513, and 514 in Table IVb.), it is at once evident that almost the whole of the ticks in the pre-adult stage at the time of treatment are immediately arrested in their development and are ultimately destroyed. This may occur even when the arsenical content of the dip is considerably lower than the quantity laid down in the official formula (8 lb. As_2O_3 per 400 gallons). Thus Table V. gives the complete history of a number of cattle treated once in a dipping fluid containing only 5 lb. arsenic per 400 gallons, which fluid allowed only odd ticks not in the adult stage at the time of treatment to reach maturity. This fact is, of course, well known from field observations, where we often find great difficulty in locating mature adult ticks on cattle in the second and third weeks after treatment, even if the dipping fluid at times is considerably lower in arsenical strength than that prescribed for the official dip.

Even if we introduce, immediately or soon after treatment, factors likely to strongly militate against the lethal effect of the arsenic, as by spraying with water (Table IVb.), we still see that the younger ticks are largely if not wholly destroyed.

The same result is shown in Experiment I., where we used artificially infested cattle carrying large crops of ticks all of the same parasitic age at the time of treatment. The observations there indicate that very odd ticks up to the seventeenth day of parasitic life are capable of escaping one treatment. The only ticks which survived in appreciable numbers were those which happened to be in the last three or four days of parasitic life at the time of treatment (nineteenth and twenty-first day).

On theoretical grounds, therefore, one would expect that, as a single treatment arrests the development of nearly all those ticks up to and including the young adult stage, a second treatment—placed at an interval of not less than five days, which will allow adults in the last four days of parasitic life to reach maturity and leave the animal—must destroy the very few ticks which escape the first treatment, and not only do this but leave a fair margin of safety.

Why is it, then, that ticks are found to be maturing on cattle even after two treatments in an arsenical dipping fluid containing as much as 9 lb. arsenic per 400 gallons?

We have always been under the impression that the thick, heavy winter coat of a tick-infested animal, particularly if the hair is very dirty and matted together, may act as a protection to the tick beneath, and so prevent the dipping fluid from coming into contact with the parasite. We have noticed in the field that when ticks escaped two treatments the survivors were almost wholly found on the upper portions of the neck, back, and loins, and occasionally on the outside of the leg between the patella and the hock. These represent those portions of the body on which the hair is both denser and longer. The point is all the more important because the region of the back and loins*, even in many very heavily infested cattle, relatively speaking, frequently carries a smaller number of the parasites than the region of the escutcheon and flank. In our experiments and observations we have never found ticks surviving two treatments in the region of the escutcheon and inner surface of the flank, though in large numbers of naturally infested cattle these areas are the most heavily infested parts of the body irrespective of the class of animal examined. In fact, in the observations carried out by us in this experiment (No. VII.) we found, that for the purposes of examination, areas of the body such as the under surface of the belly, brisket, escutcheon, and inner surface of the flank could have been entirely neglected. No survivors at any time were discovered maturing in these areas, for the ticks here are fully exposed to the application of the dipping fluid.

Where a number of ticks were found maturing on any one animal after the second treatment, in nearly all cases they were found in one or two small areas in a mass of thick, long hair, and one could not escape the conclusion that in these cases the dipping fluid failed to make contact with the tick. Animal No. 482, which was treated with two applications of a medicament containing 9 lb. arsenic, 3 lb. Stockholm tar, &c., with an interval of ten days between treatments, yielded within a week following the second treatment nearly fifty mature female ticks, a considerable number of which oviposited fertile eggs. All of the survivors were removed from a small area in the region over the transverse lumbar processes. This animal, like all others, had been thoroughly immersed at the time of both treatments.

When these ticks were discovered the day following the second treatment their condition and appearance indicated that the dipping fluid had not affected them in any way at the time of the second treatment, and the long, dense, matted hair with which the parasites were then covered probably also protected them at the time of the first application of the medicament.

Similarly with other cattle treated the indications were that where the hair is long and matted together, as it may be by means of fæces and dirt, odd ticks may be afforded sufficient protection to allow of their complete or almost complete immunity from the effects of the dipping fluid.

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* It frequently happens that with badly constructed dips, and/or with cattle inured to dipping, when complete immersion of the animal is not procured, ticks may be found maturing on such places as the top of the head and neck, or any place that has not been brought into contact with the dipping fluid.

We think the question requires more study, but the mild winter conditions in North Queensland means that very few cattle develop the heavy coats found in the more wintery parts of the State farther south, hence a good supply of suitable animals is not available to us.

Conclusions.—The evidence which we have gathered points to the following conclusions:—

1. No two treatments at intervals of three to ten days, in a medicament containing up to 9 lb. of arsenic (As_2O_3) per 400 gallons of fluid, can be relied upon to destroy all ticks in all stages on an infested animal.

2. The omission of Stockholm tar and soap from the dipping fluid does not interfere with the efficacy of the solution as a tick-destroying agency.

3. Two treatments in a solution containing 6 lb. arsenic as As_2O_3 per 400 gallons is, under field conditions, as efficacious as two treatments in a solution containing up to 9 lb. of arsenic in an equal quantity of fluid.

4. When fertile survivors are found after the second of two treatments in a solution containing 6 lb. or more of arsenic per 400 gallons, they occur under circumstances which indicate that the dipping fluid has failed to make proper contact with them.

SUMMARY.

The experimental evidence which we have been able to bring forward in the various experiments under review points to the following conclusions:—

The tick is more resistant to treatment with arsenical dipping fluids during the last three or four days of parasitic life. The point is of importance in any system of tick eradication, in that treatments must be so spaced as to prevent as far as possible any tick from reaching the resistant stage.

The application of arsenical dipping fluids prevents reinfestation for twenty-four hours after treatment but not for forty-eight hours.

If cattle are allowed to enter water immediately after treatment and remain therein for considerable periods, the efficacy of the treatment is interfered with to a considerable extent.

Light showers do not seriously interfere with treatment, provided rain does not fall within an hour after treatment and the animals are allowed time to dry.

Retention of the animals in the vat—within reasonable limits—or increasing the length of the vat does not influence the effect of the dipping fluid on the tick.

Alteration in the physical character of the fluid, such as is brought about by prolonged use, does not interfere with the efficacy of the solution as a tick-destroying agency.

No two treatments with an arsenical dipping fluid containing up to 9 lb. of arsenic as As_2O_3 per 400 gallons can be relied upon to destroy all ticks on an infested animal.

The omission of the emulsion of tar and soap from the official dipping fluid does not lessen the efficacy of the solution.

Ticks may be protected from treatment by the long, dense hair which occurs particularly in the winter time on many cattle.

Finally we might add that, although the evidence we have been able to bring forward in the above experiments helps to throw light on some of the more important points which arise when the question of tick suppression is under consideration, there are other equally important points on which evidence is also necessary before one is able to fully appreciate the difficulties presented by the problem of tick eradication under Australian conditions.

Much more work is required on the use of emulsions in dipping fluids. As the dipping fluid containing 6 lb. arsenic per 400 gallons was as efficacious under ordinary conditions as the standard fluid (8 lb.) it is not improbable that still higher dilutions could be used with equally good effects.

It appears to us that the more frequent use of dips of high dilution may prove a more efficacious method of bringing about tick suppression than the less frequent use of fluids containing larger quantities of arsenic. It certainly offers a valuable field for further research.

REFERENCES.

(1) Brunnich, J. C., and Smith, F. B.—Q.A.J., July 1914, pp. 81-92. " Factors influencing efficacy and deterioration of dipping fluids."

(2) *Ibid.*—Q.A.J., April 1915, pp. 161-163. "A new dipping fluid."

(3) Cohen, Lionel—N.S.W. Agric. Journal, Feb., Mar., April 1923. " Experiments with arsenical dipping fluids."

(4) Cooper, W. F.—Agric. Journal Union of S. Africa, v. 1910, pp. 716-721. " The tick-killing properties of sodium arsenate."

(5) Cooper, W. F., and Laws, H. E.—Parasitology, Sept. 1915, vol. 8, pp. 190-217. " Some observations on the theory and practioe cf dipping."

(6) Cooper, W. F., and Nuttall, W. H.—Journ. of Agric. Science, vol. viii., part 11, Sept. 1915. " The theory of wetting and the determination of the wetting power of dipping and spraying fluids containing a soap basis."

(7) Watkins-Pitchford, Lt.-Col. W. H.—" Tick destruction and the eradication of East Coast fever and other South African diseases by dipping." Pamphlet published by P. Davis, Port Durban, South Africa.

(8) Bulletin 1057, U.S.A. Dept. of Agriculture. " Cattle fever ticks—Methods of eradication."

(9) Bulletins Nos. 1 and 13, Bureau of Science and Industry, Commonwealth of Australia. " The Cattle Tick Pest in Australia" (1917); " The Cattle Tick Pest " (1919).

(10) Report of Royal Commission on the Cattle Tick. N.S.W. Govt. Printer, 1912.

(11) Jack, Rupert W.—" Ticks affecting domestic animals in Southern Rhodesia" —Bulletin No. 402, Dept. of Agric., Salisbury, Rhodesia.

Some Observations on the Life History of the Cattle Tick (*Boophilus australis*).*

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(*Communicated by Mr. F. A. Perkins, B.Sc.Agr., to the Royal Society of Queensland, 29th July, 1929.*)

The history of the cattle tick in Queensland shows that it entered the State from the Northern Territory at its extreme north-western corner about 1891, and from this point made little headway for the first couple of years. After the closure of the meatworks at Normanton the parasite moved rapidly south and east, its spread being greatly facilitated through movements of cattle by rail.

In 1896 the tick reached Hughenden, and before the end of the same year it had extended as far as Rockhampton. In 1899 Brisbane was reached, but owing to its slower progress south of that city to the border of the State the tick did not appear in New South Wales until 1906.

At present the parasite has established itself over all that area of Queensland where climatic and other conditions are suitable for its propagation, the line of demarcation between the infested and non-infested area being represented roughly by the watershed of the coastal rivers. Between these areas there lies a strip of country where the presence of the tick is discontinuous. In dry seasons this strip is non-infested; after a series of wet years it is liable to become infested.

The losses due to the tick are twofold. It acts as the vector in transmitting piroplasmosis (*P. bigeminum*), a disease which has caused very heavy losses in cattle in Queensland in years gone by, and even to-day is a serious obstacle in the transfer of non-immune cattle to infested areas; but apart altogether from its association with piroplasmosis it is undoubtedly an important pest of cattle, producing anæmia, tick worry, &c., and is a definite handicap to the development of the cattle industry in Queensland.

In view of these circumstances it is very important that a full and complete knowledge of the life history of the tick should be gained.

The cattle tick of Australia falls into the class of what are known as continuous feeders; that is, they pass through the whole of their parasitic life attached to the one host.

Preoviposition.—The female adult tick does not commence to oviposit immediately after reaching repletion and detachment from the host. This period between detachment and the commencement of oviposition is known as the preoviposition period, and during this period the tick

* An extract and a summary of a Paper bearing the same title, and which formed part of a thesis for the Degree of Doctor of Veterinary Science in the University of Melbourne.

usually hides beneath grass, debris, leaves, wood, &c. A series of observations showed that the period was influenced by the season of the year, and varied from a minimum of two days in summer to twelve days in winter. Roughly the periods are five to nine days in winter, four to six days in spring and autumn, and two to four days in summer.

Oviposition, or the period occupied in producing eggs, varies also according to the season of the year. The differences between the summer and winter variations were not very great. In summer, however, once ovipositing commences the majority of eggs are laid during the first week, and there is a marked tendency for ovipositing to cease abruptly, to be soon followed by the death of the tick, while during winter there is usually a gradual slackening-off of the process. The shortest period of ovipositing was five days (summer) and the longest thirty days (winter).

Egg Stage.—The egg is elliptical, dark brown in colour, and covered with an albuminous-like secretion.

Altogether 120 females were tested, and it was found that the average number of eggs per female was 2,579, the maximum being 4,269, the minimum 1,673. The greatest number of eggs laid by any one female during a 24-hour period was 731.

Incubation Period.—This varies considerably according to the season of the year. A very large number of eggs were tested out between the months of November and July, and it was found that the minimum period was fifteen days (summer) and the maximum fifty-five days (winter). These figures were obtained at Townsville, where the average winter temperature is considerably higher than some of the tick-infested areas further south, so that probably the maximum figure would be higher still in southern Queensland, or even in the higher altitudes of the North.

The fertility of masses of eggs, selected indiscriminately, was found to be very high. During six months 127 batches were tested, and of these fifty-seven showed a fertility of over 90 per cent., fifty showed a fertility of between 80 and 90 per cent., while the lowest fertility percentage noted was 68.

The above recorded figures covering the non-parasitic life of the tick indicate why such an enormous increase in parasites takes place during a normal wet season on the Queensland coast.

Influence of Immersion in Water on Egg Fertility.—Although moisture is essential to the incubation of the egg, excess of moisture, such as may occur during the submergence of large areas of land for longer or shorter periods during the wet season, might be detrimental.

Batches of eggs were tested over a period of six months. These batches were allowed to incubate for definite periods, and then split up into a series of different groups, and each group submerged for a definite period varying from one to fourteen days.

As a result of these experiments it was found that submergence for twenty-four hours at any time during the incubation period had little effect on the fertility and ultimate development of the egg. Nearly all batches submerged for seventy-two hours showed some fertile eggs, the number varying from 3 to 89 per cent.

Seven days' submergence completely destroyed several batches, though the fertility of some groups of eggs was as high as 72 per cent.

Ten days' submergence destroyed all groups but seven, but even after such prolonged immersion one group of eggs showed a fertility of 81 per cent.

Fourteen days' submergence destroyed all eggs but one group, which showed a fertility of 12 per cent.

Otherwise the observations showed that the younger the egg the more resistant it was to immersion, while the incubation period was not affected.

The flooding of pastures therefore is not likely to have a serious effect on the eggs of the tick. In fact, flooded streams possibly assist in the distribution of the parasite from one area to another.

Effect of Sunlight on the Egg.—Direct sunlight was found to have a very injurious effect upon the egg. A series of observations, somewhat along the same lines as those performed to test the effect of excess of moisture, were carried out.

Several batches of eggs were obtained and allowed to incubate for definite periods, and then exposed to direct sunlight for a short period of from one to ten hours, the observations being carried out over the first six months of 1927.

The results showed that the effect of direct sunlight for even one hour at any time during the incubation period completely destroyed many batches tested. On cloudy days, where the sun was largely obscured, odd batches withstood four hours' exposure, but the fertility was considerably reduced.

These results show the beneficial effect of shade on the developing egg, and help to explain why the tick has never been able to definitely establish itself on the open downs of Northern and Central Queensland and the Barkly Tableland of the Northern Territory.

The Larval Tick.—The young larva is very minute, extremely active, possesses six legs, and stigmal plates between the second and third row of coxæ. Under natural conditions they swarm over the herbage and occasionally collect in masses together, particularly on the shady side of blades of grass, &c., moving round during the day with the sun.

It is remarkable how these masses of larvæ detect a moving body in their vicinity and show the greatest activity when disturbed. They frequently hang on by their posterior limbs and wave the anterior in the air, this procedure facilitating their prospects of attachment to a passing host.

The maximum longevity of these larvæ is a point of very great importance, as on it depends some of the methods of eradication, such as pasture rotation, &c. A series of observations extending over fourteen months were carried out with a view to determining this point. In one series of experiments batches of larvæ, each of which consisted of several hundred individuals hatched during a single 24-hour period, were isolated in the laboratory under circumstances which prevented their escape. Some of these batches were supplied with an abundance of water, some received none, other batches were wholly shaded, some partly shaded, and some fully exposed to the sun. As the maximum longevity was set down as the period between hatching and the day on which the last larvæ was seen alive, it was possible—as there were 150 batches tested altogether—to arrive at some definite data concerning larval longevity.

The maximum longevity noted was 154 days, approximately five months, this occurring in a batch of ticks hatched in the winter, and which were shaded during the whole of the time and supplied with an abundance of moisture. Fifteen batches showed a maximum longevity of 100 days upwards, while the majority of the remainder showed a maximum longevity of between sixty and ninety days.

It was noted that with many batches all the larvæ remained alive and active for at least two months before mortality set in.

A second series of experiments were carried out in the open air by isolating small patches of grass and placing newly hatched larvæ on these patches. Moisture was provided throughout the experiment in order to keep the patches as fresh and green as possible.

Altogether forty-four batches of ticks were tested in this manner. The minimum time occupied in any one batch between hatching and the death of all larvæ was sixty-five days, the maximum 112 days.

Maximum Non-Parasitic Periods.—The maximum non-parasitic periods noted during the various recorded observations were as follows:—

Preoviposition	12 days.
Oviposition	30 days.
Incubation	55 days.
Longevity of larvæ	154 days.

The above figures, it is considered, are of considerable importance from the point of view of tick eradication. It is possible that the figures may be slightly increased in the cooler infested portions of the State, but for the greater portion of the infested area of Queensland the above figures would, we think, be found to hold good.

Seasonal Factors Influencing the Non-Parasitic Life of the Tick.—The increase in the number of ticks during a normal wet season in Queensland may be enormous. This is due to several factors. Heavy rain which is the general rule provides an abundance of moisture, the long grass provides adequate shade, while the excessive heat shortens the incubation period of the egg to a minimum. The non-parasitic life cycle may thus be completed in less than three weeks.

On the other hand the cold, dry winters are adverse to the propagation of the parasite. No rain falls over lengthy periods, and particularly in heavily stocked country the grass is eaten out and little shade may be provided for the ovipositing female. The cold weather necessitates a lengthy incubation period of the egg, which means that its chances of survival are considerably lessened.

This accounts for the inability of the tick to definitely establish itself over the downs country of Central Queensland, and for the fact that in a series of drought years the parasites may completely die out over extensive areas of country. In drought years, when a heavy mortality occurs amongst the cattle population, the reduction in the number of possible hosts is also a factor in determining the disappearance of the pest.

Parasitic Period.—In order to obtain information on the parasitic life of the tick, a series of clean animals were infested artificially. After infestation all these cattle were allowed grazing under circumstances which precluded the possibility of natural infestation, and were only placed in stalls just before the first females reached repletion.

The cattle used were of both sexes and aged from one to three years. Some of them, having been bred on clean country, had never been previously infested with ticks, others had been subject to more or less heavy natural infestation from the time of birth and were only cleansed a few weeks before being brought to experiment. Altogether fourteen animals were infested during the summer and nine during the winter.

1. *Larval Stage.*—Twenty-four hours after placing larval ticks on an animal, they will be found to have distributed themselves over the body surface, to have selected their point of attachment, and commenced to engorge. A marked predilection is noted for certain parts of the body with most animals, the most heavily infested areas comprising the flank, inguinal region and escutcheon, the neck and brisket. A tiny aerolar spot marks the point of attachment of the tick, but there is practically no exudate from the skin.

At seventy-two hours the tick has visibly increased in size, changed to a paler colour which renders it more difficult to see, especially among the lighter coloured hairs of the flank and escutcheon.

At the end of the fifth day engorgement is complete with many larvæ, and if removed from the host and placed in the laboratory at this time nymphs can usually be moulted out from most of the ticks.

During the sixth day nymphs begin to appear on many animals, the end of the seventh day sees most of the parasites in the nymphal state, though odd engorged larvæ may be present during the eighth and ninth days.

2. *Nymphal Stage.*—The nymphal tick emerges from the larval integument through the latter splitting along its sides and permitting the escape of the nymph.

Apparently the nymphal tick almost immediately reattaches itself at or close to the original point of attachment. In odd cases only were we able to find completely unattached newly hatched nymphs.

Engorgement of the nymph is rapid, and is frequently completed by the twelfth day of parasitism. Tidswell[9] records the presence of adults during the twelfth day, but we have not been able to observe them as early as this.

By the twelfth day, however, most of the ticks can be divided into two groups—one of larger and one of smaller nymphs. The numbers of each are about equal, and by weight the smaller nymph is about half the size of the larger. The small nymphs represent the male adults, the larger the females.

The nymphs which ultimately produce male adults commence to moult as a rule a few hours before the nymphs which give rise to females. Thus during the thirteenth day young female adults are comparatively rare, but on several animals a number of young male adults were found.

During the fourteenth, fifteenth, and sixteenth days large numbers of nymphs pass through the moulting stage and produce adults. Figures vary somewhat according to the animal examined, and to a certain extent with the climatic conditions prevailing, but examinations of a number of animals and covering both winter and summer shows that approximately 12 per cent. of nymphs have moulted by the end of the fourteenth day, 50 per cent. by the end of the fifteenth day, 75 per cent. by the end of the sixteenth day, 90 per cent. by the end of the seventeenth day. Odd engorged nymphs may be present on some animals as late as the twenty-first day.

The details covering the development of the tick are shown in the following table:—

TABLE SHOWING THE DEVELOPMENT OF THE TICK DURING ITS PARASITIC LIFE.

No. of Animal.	Day first larvæ moulted.	Day last larvæ moulted.	Day first nymph moulted.	Day last nymph moulted.	ADULTS DROPPED		Minimum parasitic period. Female adults. (Days).	Total. Engorged females.	Month infested.
					First day.	Last day.			
1	7th	10th	14th	19th	22	32	8	13	December
2	7th	9th	14th	20th	21	31	7	29	December
3	7th	9th	14th	20th	22	28	8	53	December
4	7th	9th	14th	19th	20	28	6	93	December
5	8th	8th	14th	19th	20	28	8	4	December
6	7th	8th	14th	20th	22	28	8	11	December
7	7th	9th	15th	20th	25	34	10	18	December
8	6th	8th	13th	18th	21	33	8	682	January
9	7th	8th	13th	17th	21	28	8	377	January
10	6th	8th	13th	17th	21	34	8	1,370	January
11	6th	8th	13th	17th	20	32	7	1,069	January
12	6th	8th	13th	17th	20	32	7	2,377	January
13	6th	8th	14th	17th	21	28	7	394	January
14	6th	8th	13th	18th	21	34	8	1,839	January
15	7th	9th	13th	20th	20	35	7	511	May
16	6th	9th	13th	20th	20	31	7	814	May
17	7th	10th	13th	20th	23	31	10	39	July
18	7th	10th	14th	20th	21	30	7	3,288	August
19	7th	10th	14th	20th	21	32	7	2,976	August
20	6th	10th	13th	20th	21	31	8	2,743	August
21	6th	10th	14th	21st	21	30	7	1,944	August
22	7th	10th	14th	21st	21	27	7	67	August
23	6th	10th	14th	21st	21	31	7	1,523	August

3. *Lesions Produced by the Nymph.*—The bite of the nymph is followed by a reaction. This is in marked contrast to the bite of the larva, which apparently produces nothing more than a tiny erythematous patch on the surface of the skin, in the centre of which the rostrum of the larvæ is inserted. In all our experimental cattle the appearance of the nymphal tick was followed during the next twenty-four hours by considerable swellings on the surface of the body. The size of these swellings varies and depends on whether they are produced by one or several nymphs. When produced by a single nymph they are circular in appearance and measure up to an inch across, but when large numbers of nymphs, especially when several hundreds are all in close proximity, the swellings may merge into quite large urticarial-like elevations. The centre of the swelling, which corresponds to the point of attachment of the nymph, may be raised as much as a quarter of an inch above the surrounding skin, but the edges are not well defined, and gradually merge into the surrounding tissues.

These swellings appear rapidly, remain for about forty-eight hours, and just as rapidly disappear. There is no doubt that they were much more conspicuous in our experimental cattle as compared with cattle naturally infested, because with the former we were dealing with the appearance in some cases of many thousands of nymphs all hatching over a very short period, while with naturally infested cattle under ordinary circumstances the appearance of the nymphs would correspond roughly to the rate at which the larvæ were being picked up in the field.

On subsidence the swellings in many cases are followed by the appearance of a serous exudate around the point of attachment of the nymph. Necrosis of a small area of skin frequently follows with the formation of a tiny ulcer. The coagulated exudate may completely hide the nymphal tick, which does not seem to be in any way inconvenienced. In animals which are possibly a little more sensitive to the bite of the nymph, the area of the ulcer may be many times the size of the nymph itself.

Infection easily follows, and where considerable numbers of nymphs are close together the small ulcers produced may coalesce, and in this way the typical tick-sore is produced. The opinion has been formed as a result of observation of the results following the bite of the nymph that it is the nymph alone which is mainly responsible for the production of "tick-sore" and for the "lumpy" condition of the skin in naturally infested cattle.

4. *Adult Stage.*—The nymphal integument splits longtitudinally and the young adult emerges. The female usually reattaches at once at the same point or else in close proximity to its original position. The male ticks, however, do not reattach, but pursue their functions in searching out the unfertilised female. Some of them will be found to have located themselves beneath the larger nymphs which produce female adults, thus showing an ability to select the female really before actual moulting has occurred.

During the first three or four days of attachment the increase in size of the female is not very great. Frequently she reaches a stage of engorgement approximately three or four times that of the unengorged state, and appears to remain so for a couple of days. It is probably at this period that fertilisation really becomes effective, because, soon after, a rapid increase in size may take place, to be followed by the final engorgement occupying only a few hours, and during which there is a relatively enormous increase in the size of the parasite.

In any attempt to collect all the engorged females from a heavily infested animal, examinations have to be carried out every few hours or many ticks will be lost.

The minimum period of parasitism of the female adult is set down as six days, the average female taking usually a day or two longer.

The first engorged females complete their parasitic life history at some time during the twentieth day. A few females in the summer time were noticed to have almost completed their engorgement by the end of the nineteenth day, but none were actually fully replete till a short time later.

The number of engorged females removed and the days on which removed are shown as follows:—

Day after Infestation.	Summer.		Total.	Winter.
	January.	February.		
20th	5	25	30	52
21st	13	1,344	1,357	878
22nd	60	2,493	2,553	1,538
23rd	62	1,743	1,805	2,391
24th	43	634	677	3,202
25th	25	154	179	3,078
26th	10	83	93	2,356
27th	14	43	57	1,426
28th	12	33	45	794
29th	5	10	15	151
30th	2	6	8	37
31st	2	7	9	15
32nd	1	7	8	17
33rd	0	2	2	5
34th	3	4	7	3
35th	0	0	0	1
	257	6,588	6,845	15,944

In the case of the summer observations it will be noted that the maximum number of adults dropping off was reached on the twenty-second day; in winter the maximum number was attained on the twenty-fourth day.

The male ticks evidently disappear about the same time as the females, because after the disappearance of the latter, even in heavy infestations, it is difficult to obtain males. In one observation we found males still present on the forty-sixth day after infestation, the last female having dropped on the twenty-ninth day. It is therefore possible that under natural conditions a single male may fertilise several females.

As a result of observations made on cattle which were infested with a few ticks, all widely scattered over the surface of the body, the conclusion was drawn that the female adult possibly fails to reach a state of repletion if not fertilised by the male. Attempts to thoroughly test the question by removing fully engorged nymphs from infested cattle and permitting them to moult in the laboratory and then inducing the young female adults to attach themselves to a clean host proved abortive. None of the young females could be induced to reattach to a fresh host.

The comparative sizes of the tick at different stages of its parasitic life were determined by gathering parasites of definite ages and ascertaining the number required to make one gram.

Details are give below—

Stage of Life History.	Approximate number weighing 1 gram.
Egg	25,000
Larvæ (unengorged)	50,000
Larvæ (engorged three days)	11,500
Larvæ (engorged five days)	6,000
Nymph (unengorged)	8,000
Nymph (small, fully engorged)	1,200
Nymph (large, fully engorged)	650
Female adult (unengorged)	780
Female adult (engorged)	4·7

This table shows that seventy-two hours after attachment the tick is already four times its original size (by weight), and by the end of the fifth day eight times as large.

The unengorged nymph is somewhat lighter than the engorged larvæ; similarly the unengorged female adult is lighter than the engorged nymph from which it arises.

The smaller engorged nymphs, or those which give rise to male adults, are about half the size of the larger nymphs which produce female adults.

Little difference between the periods occupied during the summer and winter by the tick in the different stages of its parasitic life history was observed. In summer the ticks develop on the whole a little more rapidly than in winter. The total period of parasitism of the tick in summer averages twenty-two days, in winter twenty-four days. The maximum period occupied by any one tick was thirty-five days.

Heavy infestations develop slightly quicker than light ones, while ticks develop just as rapidly on those portions of the skin which are thick as on the lighter and thinner areas.

Neither age, sex, nor previous freedom from the parasites had any influence on the development of the ticks. Cattle heavily infested all their lives and cleansed just before being brought on to experiment presented no difference from animals which had never been previously subject to infestation, whether natural or otherwise.

Factors Influencing the Parasitic Life of the Tick.—An important feature noted in all the experiments designed to obtain information covering the parasitic life of the tick was that only quite a small percentage of the larval ticks which were used for infestation ever developed and reached maturity. This was observed with all cattle each and every time they were infested. The absence of dead ticks in a partly developed state indicated that the ticks die before attachment or else soon after, and before they begin to engorge and develop. Dead larval ticks can be found, but they are very hard to locate. Of course, owing to their size they could be present in large numbers and still be difficult to locate. American observers have also recorded the same feature, and state that the ration received had considerable influence on the development of the parasite. In our own observations cattle grazed under natural conditions presented no difference from cattle stall-fed during the whole of the parasitic life of the tick. Alterations in the rations of the stall-fed cattle made no apparent difference in the result.

We were able to test out the resistance of some very poor cattle in the drought of 1926, and found a very high mortality amongst the larvæ used for infestation. A year later, in 1927, the same cattle but in much better condition showed a similar resistance.

Summing up, the conclusion was reached that neither the condition of the host nor the ration received had any influence on the development of the parasite.

The question of tick resistance, in the sense that but a small percentage of viable larvæ placed on any animal ever reach maturity, leads to the further question of tick resistance and tick immunity.

Tick Habituation and Immunity.—This question of tick immunity has been acutely debated in Queensland at different times, particularly because of claims which have been made to the effect that such resistance, known to occur in a very marked form in some animals, could be transferred from one animal to another by artificial means.

It is known that many ticks inject a toxin into the host, and there is some evidence to show that, with some ticks at least, recovery from the effect of the toxin leaves behind a fairly solid immunity. Thus with *Ixodes holocyclus* it is generally held that a recovery from the effects of the bite of the adult is followed by a strong resistance.

With *Boophilus australis* the evidence concerning the production of a toxin is provided by the swellings that occur after the attachment of the nymphal tick. These swellings are quite characteristic and are just as evident in cattle after years of infestation as with cattle infested for the first time.

Many cattle, however, show a resistance practically from birth—particularly certain breeds. An animal with a strain of Brahmin is usually more resistant, while our experience has led us to the belief that many Jerseys and Fresians are also highly resistant. Odd animals of any breed may be found to be carrying but few developing parasites, although running on obviously heavily infested pasture.

Our own observations on the question of tick resistance and tick immunity led to the following conclusions:—

1. That all animals display considerable resistance to the tick in the sense that only a small percentage of larval ticks—apparently quite viable when placed on the animal—ever reach maturity.

2. That the mortality occurs before the larval ticks attach, or else soon after.

3. That many cattle appear to possess this quality of resistance when infested for the first time.

4. That the bite of the nymph in many cases is followed by a transient swelling, and this swelling is probably due to the injection of a toxin.

5. That prolonged exposure to the tick rarely appears to increase the animal's resistance.

Host Relationship.—Although a fairly strict parasite of cattle, the pest does not confine itself to the one host. Occasionally single horses will become heavily infested with developing ticks, while others exposed to an apparently equal degree of infestation are but slightly affected. The reason is difficult to obtain. Sheep weakened by drought conditions are frequently heavily infested with ticks.

Ticks have not been observed to develop on any native animal or bird.

The infrequency under ordinary circumstances with which ticks attach themselves to any other host than cattle is a point of great importance in any system of tick eradication.

Natural Enemies.—Unfortunately, perhaps, the tick in Australia appears to have but few natural enemies.

The willie-wag-tail (*Rhipidura motacilloides*) appears to be one of the most formidable enemies of the tick, but it is not a very common bird in parts of Queensland.

The crow frequently assists, while domestic poultry help to destroy female adults on the ordinary house cow.

Conclusions.—The above observations have all been set down because of the paucity of literature on the subject in Australia, in spite of the seriousness of the parasite.

They show that there are some slight differences between the life history of the tick in Australia as compared with America; these variations can probably be accounted for by diversity of climate.

The tick has tended for years to establish itself in Australia everywhere where conditions are favourable, and it is probably only being arrested in New South Wales by vigorous counter measures.

REFERENCES.

1. Fuller, Claude.—Agric. Gazette N.S.W. Vol. 7, p. 760-787. Qld. Agric. Jrnl. May, 1899: "Notes on Queensland Cattle Tick."

2. Gilruth, J. A.—Proc. Roy. Soc. Victoria 25 (N.S.) 1912, p. 351-357.

3. Graybill, H. W.—Bulletin 130, Bureau Animal Industry U.S.A., "Studies on the Biology of the Texas Fever Tick."

4. Hunt, Sidney, and Collins, William.—Report of Special Commission of Government of Queensland to U.S.A., 1896.

5. Hunter, W. D., and Hooker, W. A.—Bulletin 72, Bureau of Entomology, U.S.A. Department of Agriculture.

6. Hull, Munro.—Qld. Agric. Jrnl. 1912, p. 294-296, "The Cattle Tick—A Remedy."

7. Johnston, T. Harvey, and Bancroft, Miss M. J.—"A Tick-Resistant Condition in Cattle," Proc. Roy. Soc. Qld. 1917, page 219.

8. Lewis, J. C.—Bulletin of the Northern Territory No. 8, Veterinary and Stock Report, July 1919.

9. Tidswell, Frank.—"Protective Inoculation Against Tick Fever," Dept. of Public Health, N.S.W., 1900.

10. "The Cattle Tick Pest," Bulletin 13, Bureau of Science and Industry, 1919.

11. Report of N.S.W. Royal Commission to U.S.A. to Investigate Methods of Suppressing Cattle Tick, 1913.

A Record of Devonian Rhyolites in Queensland.

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One Text-figure.

(*Read before the Royal Society of Queensland, 29th July, 1929.*)

The purpose of this communication is to review the existing evidence of Devonian rhyolites in Queensland and to place on record several other extensive rhyolitic series discovered by one or other of the authors within the last few years.

(a.) Previously Known Localities.

1. E. C. Saint-Smith[1] in 1922 described rhyolites from two localities within the Kangaroo Hills mining fields, and assigned both occurrences to the Devonian period. The first of these (a series of spherulitic rhyolites from the Clarke River area, near Wando Vale) was found to lie unconformably below a sandstone series containing *Lepidodendron,* which latter was referred to the Lower Carboniferous period. The series containing these spherulitic rhyolites can be traced towards Oaky Creek, where "they are seen to pass suddenly into highly metamorphosed quartzites, slates, limestones, tuffs, &c.," with which are interbedded rhyolites, spherulitic in part. These "Kangaroo Hills formations" are stated by Saint-Smith to overlie the limestones at Burdekin Downs which the contained fossils prove to be of Middle Devonian age. Saint-Smith concludes—"It is therefore reasonable to assume that the Kangaroo Hills Series [including the rhyolites] must, for the present, be assigned to an Upper Devonian age."

2. H. I. Jensen[2], in summarising the geology of the Mount Coolon area, states—"The highly metamorphosed and steeply inclined garnetiferous quartzites and schists, probably early Devonian, were followed by late Devonian dacite eruptions and later rhyolitic eruptions." He further states that "The rhyolites range from almost aphanitic glassy varieties to coarse porphyries."

(b.) New Localities.

3. In May 1928, Bryan, while investigating the sedimentary series a few miles to the west of Herberton, came on an extensive development of beautifully banded rhyolites and interbedded rhyolitic tuffs and agglomerates. The associated sedimentary rocks were fine-grained sandstones, micaceous sandstones, siliceous greywackes, conglomerates, quartzites, shales, and cherty shales. The strike varied between N. and N.W. The thickness of the rhyolites and rhyolitic tuffs is estimated as at least 2,000 feet.

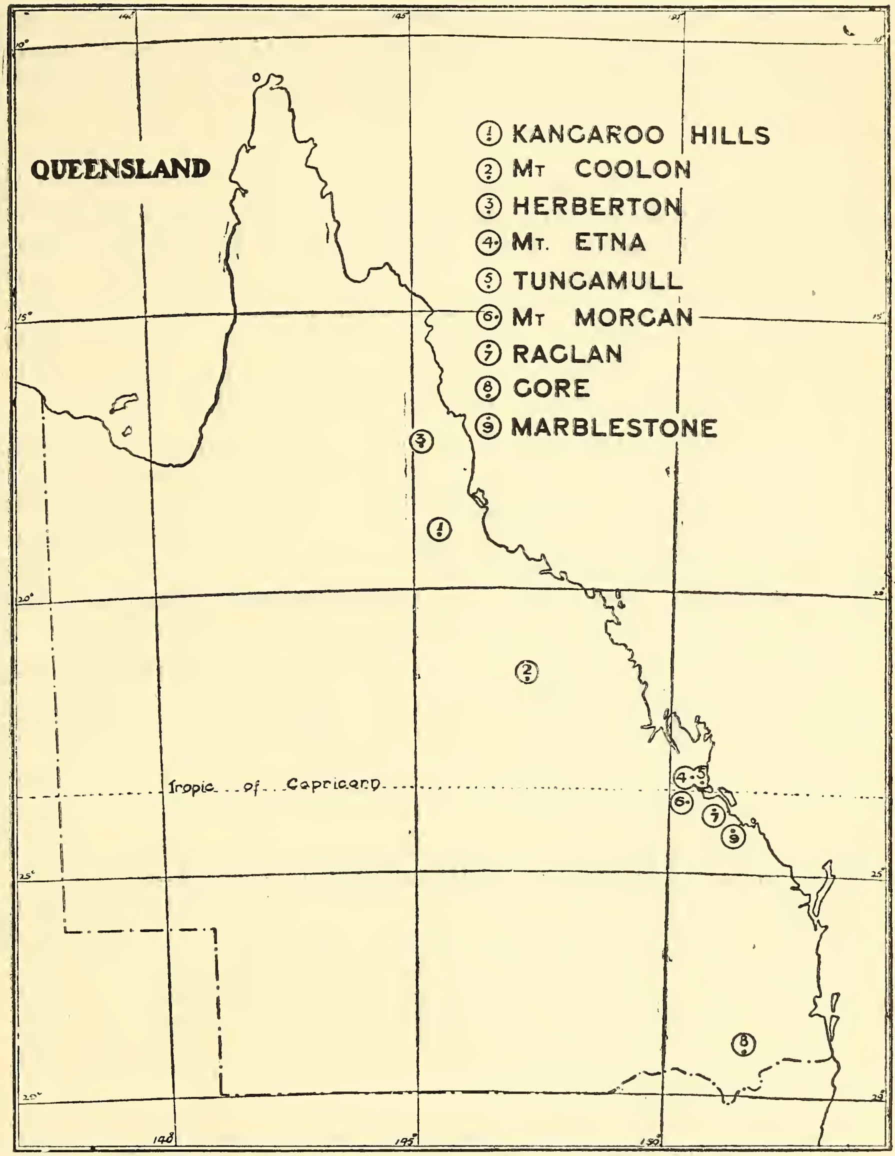
The age of the series containing the rhyolites is uncertain, but it forms part of that extensive area of metalliferous sediments to which Jack[3] gave the name Hodgkinson Beds, assigning them to the Devonian period partly on palæontological evidence. In the Newellton district, to the west of the area in which the rhyolites were found, Stirling[4] reported and described a younger non-metalliferous series containing *Rhacopteris* lying unconformably above rocks of Jack's Hodgkinson Series. The rhyolites are therefore pre-Carboniferous, and it seems reasonable to assign them to the Devonian period.

4. In 1926 Whitehouse found, in the district around Mount Etna, about 15 miles north-west of Rockhampton, an extensive Devonian series of rhyolites and rhyolitic tuffs with interbedded limestones, shales, and radiolarian cherts. These deposits recently were recorded by him under the name of the "Etna Series."[5] Serpentines of Devonian or Carboniferous age, belonging to the Great Serpentine Belt of Eastern Australia, have intruded these beds; while at a later period there have been extensive intrusions of basic and sub-basic rocks in the form of small bosses and numerous associated sills. Limestones in this area were recorded by Jack[6], Rands[7], and Ball[8], while Rands also found Devonian corals. The rhyolites, however, seem to have escaped attention, although the "silicified shales" of Mount Etna mentioned by Rands really represent these rocks. In Rands's report the surrounding rocks were recorded as Permo-Carboniferous. This error was due to a mistaken identification of a frondescent *Favosites* as a species of *Stenopora.*

The series in the Mount Etna district has an average strike of about 80° west of north, and dips uniformly to the south at about 30°. The beds were traced in a north-south direction for 6 miles. Their extension further north has not yet been traced, while to the south they disappear under deposits of alluvium. Still further to the south at the mouth of Etna Creek they reappear. At this locality, however, the beds strike N.W. and are almost vertical, the dips being to the N.E. They are very highly sheared and altered, suggesting the proximity of a fault and, possibly, also that they represent the southern limb of a syncline.

On these figures, assuming there has been no strike faulting, the minimum thickness of the series would appear to be about 15,000 feet, massive rhyolites, often with fluxion structure, forming the dominant rock type. Numerous limestone lenses have been found, some of them of very considerable thickness. Species of *Atrypa, Spirifer, Actinostroma, Favosites, Alveolites, Litophyllum, Heliolites, "Cyathophyllum," Phillipsastrea,* and the peculiar tryplasmid form, previously recorded from Silverwood by Richards and Bryan[9], have been found in these lenses. The question of the precise position within the Devonian indicated by the fossils is, however, left for discussion in a further paper.

To the east and west these beds were traced for considerable distances where, on each side, they passed under alluvium (near Yaamba on the west and Mount Hedlow on the east).



5. In more recent years the same author (F.W.W.) has found the rhyolites of the Etna Series in other parts of Central Queensland. In the railway section from Tungamull to Naukin Junction, on the Emu Park railway line, similar rhyolites* appear, following upon the Emu Park phyllites. The relationship of the phyllites to the Etna Series has not been observed in the field; but since the lower shale beds in the Etna Series in this area are themselves phyllitic, the relationships are probably

*These rocks lie to the east of the alluvial deposits of Mount Hedlow, and probably represent a continuation of the Etna Series, which were found to disappear to the west beneath this alluvium.

conformable. On the eastern slopes of Mount Sliepner the rhyolites of the Etna Series were seen to be followed conformably by a great thickness of andesitic tuffs and agglomerates. These tuffs are typically developed at Mount Berserker. No limestones have yet been seen in this section.

6. In the Mount Morgan district there is a great development of rocks of the Etna Series, particularly to the south of Mount Morgan, in the south-westerly portion of the parish of Plews. In that parish the rocks again are typical rhyolites with interbedded limestone lenses. No fossils, other than crinoid stems, have been found in the limestones. The well-known ''porphyries'' and ''ribbon jaspers'' of the mining area of Mount Morgan* appear to be typical rhyolites of this series intruded by the granite which forms the country rock around the town.

In the parish of Plews the Etna Series strikes N.N.W., dipping at about 25° to the E.N.E. Conformably succeeding this series is a vast thickness of andesitic tuffs and agglomerates.† Although generally like the series at Mount Berserker, the beds in the parish of Plews include conglomerates, with well-worn pebbles up to 2 ft. in diameter set in a matrix of andesitic tuff. They also contain limestone lenses with an abundant Devonian fauna of corals, stromatoporoids and brachiopods.

The lower portion of the Etna Series has not been observed anywhere in this area. To the east the beds have been folded into a syncline, the centre of which is occupied by the fossiliferous andesitic agglomerates.

7. The Etna Series reappears along the main railway line between Rockhampton and Raglan, where the beds strike N.N.W. and dip to the S.W. In this region rhyolitic tuffs appear to be more abundant than rhyolite flows. Limestone lenses are numerous and very large, and the well-known fossiliferous limestones of Marmor and Raglan are within this series. At Raglan, the most westerly locality where the Etna Series has been traced, the lower shale beds are phyllitic like those of Tungamull; while still further to the west, phyllites of the Emu Park Series are found. As at Tungamull, the field relationships of the two series have not yet been investigated; while the developments further to the south are not known.

8. Recently, Bryan has had the opportunity, through the courtesy of Mr. R. C. Hamilton of Warwick and of Mr. J. D. Gibson of Hunter's Hill, of inspecting an area in Portion 4v, parish of Moynalty, some 7 miles south-east of Gore, in Southern Queensland. In this locality a thickness of several thousand feet of chertified rocks was examined. The origin and true nature of these cherts was obscure until there were discovered on several horizons excellent examples of spherulitic rhyolites.

* See, particularly, G. S. Hart's paper: ''Further Notes on the Geology of Mount Morgan,'' Aust. Inst. Mining Eng., N.S., No. 6, 1912, p. 3. This little-known paper is a very valuable account of the geology of the area.

† These form the so-called ''Carboniferous andesites'' of the Mount Morgan district.

The rhyolites were themselves chertified, but the nature of the weathered surfaces left no doubt as to their origin. It would seem reasonable to suppose that the whole series of cherts was largely, if not entirely, formed from the alteration of flows of rhyolite, and the absence of the stratification characteristic of cherts formed by the silicification of shales or other sediments certainly supports such a supposition. The age of the rhyolites is far from certain, but they appear to overlie a series of limestones and massive red jaspers similar to those which have in other parts of Queensland been assigned to the Lower Devonian. In these circumstances they may be regarded tentatively as of Devonian age.

General Remarks.

During the past few years, Süssmilch[10] and Browne[11] have published general accounts of the igneous activity of New South Wales, while Richards[12] has dealt with that of Queensland. One of the most remarkable differences in the accounts of the two States concerned the rhyolitic lavas of the Devonian period. Süssmilch points out that the Lower Devonian or "Volcanic series" of the Murrumbidgee area is made up entirely of rocks of volcanic origin, consisting of rhyolitic lava flows and tuffs which are the equivalents of the Snowy River Porphyries of Victoria. In the succeeding Murrumbidgean epoch, 8,000 feet of a total of 12,000 are composed of rhyolitic tuffs or tuffaceous sediments. "These two epochs," writes Süssmilch, "together constitute one of the great volcanic epochs of Australia."

It is interesting to contrast this statement with Richards's summary of Devonian activity in Queensland, where rhyolites are not even mentioned.

The recent discoveries announced above go far to remove this marked discrepancy between the records of igneous activity in Queensland and in New South Wales. Although the authors admit that there are no strong *a priori* reasons for assuming a close parallelism of igneous activity in the two States in Devonian times, there is a marked stratigraphical similarity with which the igneous record now seems to be in harmony.

The absence of volcanics of a rhyolitic facies from the extensive development of Devonian sediments in New England calls for some comment, in view of the great development of such rocks in the Murrumbidgee area to the south, and the great geographical range of those now recorded from Queensland. Two possible explanations present themselves, namely:—(1) That for some reason unknown there was no volcanic activity of a rhyolitic nature in the New England area, and (2) that the equivalents of the Murrumbidgee Series are missing from the geological sequence of New England. The latter explanation reopens the old controversy with regard to the spatial and temporal relationships of these two developments of Devonian rocks in New South Wales, but it is not the intention of the authors to pursue that theme in this paper.

Whether all of the areas of rhyolitic activity in Queensland are to be regarded as exactly contemporaneous with the similar activity in

New South Wales, or whether they are even contemporaneous with each other, is a question that can be decided only when each of these areas has been studied in much more detail than has as yet been attempted.

Appendix.

9. Since the above paper was read, Miss D. Hill, B.Sc., has discovered a rhyolite (specimens of which she kindly collected for the authors) at Marblestone, some 20 miles south of Gladstone. The rhyolite is associated with bands of fossiliferous Devonian limestones, and strikes with them a few degrees west of north, the dip being approximately vertical. Miss Hill's discovery makes an important addition to our knowledge of the Devonian rhyolites of Queensland.

REFERENCES.

1. Qld. Govt. Min. Jour., 1922, p. 309 *et seq.*
2. Qld. Govt. Min. Jour., 1921, p. 492.
3. Aust. Assoc. Adv. Sci., 1888, p. 5.
4. Monograph on Silver Valley, 1904.
5. Qld. Govt. Min. Jour., 1928, p. 441.
6. Geol. and Pal. of Queensland (Brisbane 1892), p. 91.
7. Qld. Geol. Surv. Pub. 86.
8. Qld. Geol. Surv. Pub. 194, p. 13.
9. Proc. Roy. Soc. Qld., vol. xxxvi., 1924, p. 98, pl. xv., figs. 1, 2.
10. Pres. Add. Roy. Soc., N.S.W., vol. lvii., 1923, p. 18.
11. Pres. Add. Linn. Soc., N.S.W., vol. liv., 1929.
12. Pres. Add. Aust. Assoc. Adv. Sci., 1924, p. 278.

Contribution to the Queensland Flora, No. 4.

By C. T. White, Government Botanist, and W. D. Francis, Assistant Government Botanist.

Plates IX and X.

(*Read before the Royal Society of Queensland, 26th August, 1929.*)

The last contribution (No. 3) appeared in volume xxxvii. of these Proceedings, pp. 152-167. The present contribution contains descriptions and illustrations of two new species. A number of species are recorded for the State for the first time. A description of the flowers of *Flindersia lævicarpa* White & Francis, is included; this species was described from fruit-bearing specimens only. Opportunity is also taken to give locality records of a few species whose range was previously little known.

Order RUTACEÆ.

Flindersia lævicarpa White and Francis. Described from fruit-bearing specimens. Flowering specimens have been collected by Mr. T. Fuller of Gadgarrah, Atherton Tableland, and the following description of them is given:—Panicles terminal or in upper leaf axils, up to 10 in. (25 cm.) long. Calyx broadly cupular, about $\frac{1}{12}$-in. (2 mm.) across, lobes 5, ovate, less than $\frac{1}{24}$-in. (1 mm.) in length. Petals puberulent, ovate or narrowly ovate, nearly $\frac{1}{12}$-in. (2 mm.) long. Stamens less than half the length of petals; anthers reniform; filaments and staminodia (when present) very short and almost gland-like. Disk crenulate. Ovary globose, without conspicuous style or stigma.

Order RHAMNEÆ.

Sageretia hamosa Brongn. Freshwater Creek, below intake (Cairns water supply) near Cairns: W. D. Francis, 7–7–1928. Scandent shrub. Specimens were forwarded to the Director, Royal Botanic Gardens, Kew, for specific identification. In a letter the Director writes—" Mr. V. S. Summerhayes has examined the specimen and reports that he cannot distinguish it from *S. hamosa* Brongn., a native of Southern India. *S. costata* Miq. from Java and Sumatra also seems to be identical with this species."

Pomaderris ligustrina Sieb. Brookfield, near Brisbane. Free flowering shrub about 3 ft. high, only a few bushes seen. Mrs. B. F. Cribb flowering specimens, 3–9–1928. This is the first record of the occurrence of this species in Queensland.

Order SAPINDACEÆ.

Dodonæa hirsuta Maid. & Betche. Stanthorpe: J. W. Passmore. October, 1920. This record brings the known range of the species well within Queensland territory.

Order LEGUMINOSÆ.

Sesbania aculeata, Pers. var. **erubescens** Benth. Leichhardt River, North-western Queensland : Dr. W. MacGillivray (ex Herbarium A. Morris Nos. 2145, 2345). A definite Queensland locality for a little-known plant.

Cyclocarpa stellaris Afz. Kelsey Creek, near Proserpine, North Queensland ; Rev. N. Michael (No. 949). A new record for the State. Determination verified at Royal Botanic Gardens, Kew. Previously recorded for Sierra Leone and the Cameroons, Tropical Africa.

Cassia neurophylla W. V. Fitzgerald. Journal and Proceedings Royal Society of Western Australia, vol. 3, p. 147, 1918. Specimens of this species were kindly forwarded by Mr. W. M. Carne, late Botanist and Plant Pathologist of Western Australia, for comparison with *Cassia neurophylla* White & Francis, these Proceedings, vol. xxxvii., p. 156, 1926. The comparison leaves no doubt that the two names are applied to the same species. On account of priority in publication W. V. Fitzgerald's name takes precedence, and, in consequence, our name becomes a synonym.

Labichea Brassii n. sp. Plate IX. Frutex ramulis teretibus pubescentibus vel hirsutis ; foliis 3–5 foliolatis, rhachide pubescenti, foliolis anguste ovatis vel ellipticis supra asperulis subtus pilis sericeis longis vestitis, margine recurvis, ad apicem valde mucronatis, utrinque reticulatis ; racemis axillaribus rhachide pubescenti vel hirsuto ; sepalis 4 lanceolatis vel anguste triangularibus acuminatis, sepalis supremis et sepalis infimis majoribus et extus hirsutis ; petalis 4, glabris ; staminibus 2, antheris linearibus ; ovario dense tomentoso, breviter stipitato, stylo glabro ; legumine elliptico ad apicem obliquo, pilis longis sparse vestito.

A shrub. Branches, leaf rhachis, rhachis of inflorescence and outer side of outer calyx segments pubescent or hirsute. Branchlets terete. Leaves pinnate. Leaflets 3–5. The lower pair of leaflets are mostly inserted on the leaf rhachis at or near its junction with the branchlet ; sometimes there is a distinct common petiole up to 3 mm. in length. Leaflets asperulous above, clothed with long fine silky hairs beneath, ovate, elliptical or elongate-elliptical, margins recurved, prominently and rigidly mucronate at apex, prominently reticulate on both surfaces ; lateral leaflets on petiolules 1–2 mm. long, petiolule of terminal leaflet 2–3 mm. ; blade of lateral leaflets 10–25 mm. long, 2–3 times as long as broad ; blade of terminal leaflet 25–40 mm. long, $2\frac{1}{2}$–$3\frac{1}{2}$ times as long as broad , the leaf dimensions include the 2–3 mm. long spinulose point. Racemes axillary, pubescent or hirsute, 1·5–3 cm. long. Pedicels 5–7 mm. long. Sepals 4, lanceolate or narrowly triangular, acuminate, 6–10 mm. long ; the uppermost and lowermost sepals are hirsute on the outside and are somewhat larger and firmer than the lateral ones which they enclose in the bud. Petals 4, yellow, tinged or spotted with red, glabrous, 9–11 mm. long. Stamens 2 ; filaments 1 mm. or less in length ; anthers linear, 4–7 mm. long. Ovary densely tomentose, obliquely ovate, on a short stipes almost 1 mm. long ; style reddish, glabrous, about 3 mm. long. Pod elliptical, oblique at apex, finely hirsute especially on margins, on a stipes 1–2 mm. long.

Labichea Brassii (new species). Natural size.

[*Face page* 140.]

Photo.: Dept. of Agriculture and Stock.

Locality: Forest Home Station, Gilbert River, North Queensland. L. Brass.

Allied to *L. rupestris* Benth. and separated from *L. rupestris* by its pinnate leaves. The species is named after its collector, Mr. L. Brass. A specimen of the species was forwarded to Mr. F. J. Rae, Government Botanist, Victoria, for comparison with material in the National Herbarium, Melbourne. In reply, Mr. Rae stated that there is an exactly similar specimen in the Herbarium from Gilbert River, collector R. Daintree, labelled F. v. Mueller *Labichea nitida* var. pinnata. In his Fragmenta, vol. 10, p. 7, 1876-1877, Mueller refers to this specimen from Daintree as a pinnate-leaved variety of *Labichea nitida*. Our specimens do not appear to represent a variety of *L. nitida* Benth. as they have only 4 sepals and 4 petals and not 5 as in L. nitida.

Albizzia xanthoxylon n. sp. Plate X. Arbor partibus junioribus ferrugineo-pubescentibus; foliis bipinnatis; pinnis 1-jugis; foliolis 3–5 jugis; pinnulis petiolulatis ovatis vel lanceolatis, apice obtuse acuminatis, basi saepe obliquis, supra nitidis, venis et venulis utrinque prominulis; paniculis magnis et terminalibus; capitulis 20–30–floris; floribus sessilibus, calyce cylindrico 4– vel 5–dentato, dentibus minutis triangularibus, apice puberulis, corolla 4– vel 5–lobata, lobis ovatis, apice puberulis, tubo cylindrico; staminibus numerosis, antheris reniformibus minutis; ovario glabro fusiformi tenuiter stipitato, stylo tenui; legumine late lineari atro-castaneo, valvis extus reticulatis; seminibus transversis planis orbicularibus.

Wood and pith of branchlets yellow; young parts and rhachis and branchlets of the inflorescence ferrugineous pubescent. Petioles 1–2·5 cm. long. Leaves on flowering branchlets consisting of 1 pair of pinnæ, each pinna with 3–5 pairs of leaflets. Petiolules 3–6 mm. long; leaflet blades ovate or lanceolate, obtusely acuminate, midrib, lateral nerves, and reticulate veins visible on both surfaces, upper surface glossy, 3–5 lateral nerves on each side of midrib, 3·5–9 cm. long, 2–2½ times as long as broad. Panicle large and terminal, the ultimate branches bearing fascicles of 20–30 sessile flowers. Flowers glabrous except puberulent apices of calyx lobes and corolla lobes. Calyx cylindrical, 2–3 mm. long, 1 mm. diam., teeth 5 or 4, minute, subtriangular. Corolla 6 mm. long, lobes 5 or 4, ovate, 2 mm. long; tube cylindrical. Stamens numerous, 9–10 mm. long; tube cylindrical 4 mm. long, free from corolla tube; anthers reniform, minute. Ovary glabrous, fusiform, on a slender stipes 2 mm. long; style slender, 7 mm. long. Pods strap-shaped, 7–12 cm. long, 17–20 mm. wide, surface reticulate. Seeds orbicular, flat, 10–15 mm. diam.

Locality: Atherton District, North Queensland, Overseer Crothers of Provisional Forestry Board, end of October, 1927.

Among Australian species of the genus the new species resembles *Albizzia procera* in some ways, but is distinguished from *A. procera* by the leaflets tapering towards the apex.

ORDER RHIZOPHOREÆ.

Bruguiera sexangula Poir. (**B. eriopetala** W. & A.) North Queensland coast without specific locality : G. Tandy XII., 1928. A new record for the State. The species is distributed in Southern India, Malay Peninsula and Islands, and China.

ORDER MYRTACEÆ.

Agonis lysicephala F. v. M. Shrub 4–8 ft. Yarrabah, North Queensland ; Rev. N. Michael (No. 1648). This is a new locality record for a little-known plant. The Rev. Michael's note on the species may be of interest :—" On a large dead stump on the side of the road I saw a big bundle of it tied together and drying in the sun. Hence the dead appearance of the specimen. I remember often having seen bundles lying about drying. The natives shake off the dead leaves and fruits and use the bundles as rough brooms to sweep round their huts. They told me it is only gathered at a certain swampy region."

Eucalyptus odontocarpa F. v. M. Between Headingly and Barkly Downs Stations, near the Northern Territory Border, Queensland : Dr. W. MacGillivray (No. 2172). (Received from A. Morris.) Dr. MacGillivray writes :—" Specimens of this tree were collected after crossing the Templeton River, between Headingly and Barkly Downs Stations, in lightly timbered porcupine country where there were numerous termitaria. It is a mallee-like gum, several stems growing from a common base." The species was previously known from the Northern Territory and the Kimberley District of North-Western Australia.

Eucalyptus quadrangulata Deane & Maiden. Parish of Gladfield about 32 miles from Warwick, Darling Downs ; Forest Factor W. J. Gorman. Determined by Mr. W. F. Blakely of the Botanic Gardens, Sydney. Mr. Gorman writes :—"A tree, in appearance like gum-topped box, having all the appearances of that species both in field characteristics and appearance of the wood. Some of the trees cut 80 ft. of timber clear to the first limbs. The only place I have noted this particular species occurring is on the State Forest Reserve 405, Parish of Gladfield, situated on the western summit of the Great Dividing Range, about 32 miles from Warwick and about 12 miles from Maryvale railway station. It occurs in scattered clumps on the spurs separating the waters of the Goomburra Valley and Maryvale Valleys, and about 1 mile to 1½ miles from the summit of the Great Dividing Range. It occurs chiefly on open forest areas on the very summit of spurs. In one instance only a clump of trees was noticed on the edge of a dense vine scrub half way down one of these spurs." Previously only known from New South Wales.

ORDER CAMPANULACEÆ.

Isotoma longiflora Presl. Naturalised about Innisfail, North Queensland : H. G. Ladbrook, C. T. White. A native of the West Indies ; naturalised in Java. A new record for the State.

Albizzia xanthoxylon (new species). Inflorescence-bearing branchlet on right. Leaf on left.

Photo.: Dept. of Agriculture and Stock.

[*Face page* 142.]

ORDER EPACRIDEÆ.

Leucopogon muticus R. Br. Wallangarra, New South Wales–Queensland border ; J. L. Boorman, vii., 1904. Inglewood ; C. T. White. Plunkett, about 30 miles south-west of Brisbane ; C. T. White (No. 5591), 24–2–29. A new record for Queensland. The Wallangarra specimens are from the National Herbarium, Botanic Gardens, Sydney, and bear the following note :—" The collector is doubtful whether the specimens were collected in Queensland or New South Wales. They are very imperfect, but we have no better specimens from this locality." The Plunkett specimens match the Wallangarra ones perfectly ; both differ from the type, which grows from Port Jackson to the Blue Mountains, in the leaves being acute, not "obtuse or with a minute callous point" as described in the "Flora Australiensis" ; the floral parts however seem to agree very well.

ORDER MYOPORACEÆ.

Myoporum platycarpum R. Br. Reserve 79, Whetstone, near Inglewood, approaching border of New South Wales : R. H. Doggrell. As the specimens bear leaves only, flowering or fruiting material is required for confirmation. Not previously recorded for Queensland.

ORDER ILLECEBRACEÆ.

Paronychia brasiliana D.C. Toowoomba, F. B. Coleman, 3–12–1927. A native of Southern Brazil. We are indebted to the Director, Royal Botanic Gardens, Kew, England, for the specific determination.

ORDER CHENOPODIACEÆ.

Roubieva multifida Moq. A native of South America but now widely distributed over the warm temperate and sub-tropical regions of the world. A new record for the State. The Clerk, Rosenthal Shire Council, Warwick, wrote, under date 13–1–1928 :—" I send you a specimen of a plant brought in by a Councillor from Leyburn. It is a strong grower and the leaders spread along the ground."

ORDER LORANTHACEÆ.

Loranthus Gaudichaudii D.C. Inglewood (approaching border of New South Wales), parasitic on *Melaleuca decora* Salisb. : C. T. White (No. 6143), 28–11–1922. Shrub with blood-red flowers. Not previously recorded for Queensland.

ORDER EUPHORBIACEÆ.

Poranthera corymbosa Brongn. Messines, via Cottonvale, Stanthorpe District : M. Greener. Not previously recorded for Queensland.

Changes in Osmotic Pressure in Relation to Movement of *Mimosa Pudica.*

By D. A. HERBERT, D.Sc. (Department of Biology, University of Queensland).

(*Read before the Royal Society of Queensland, 26th August, 1929.*)

In a former paper[1] on the effect of various reagents, including anæsthetics, on the movement of *Mimosa pudica,* evidence was presented in support of the theory that anæsthesia, in so far that it implies a suspension of sensitivity, is a term which cannot properly be applied to the effect of ether and chloroform on the sensitive plant. The evidence may be summarised as follows:—When the living plant is subjected to the action of chloroform or ether no suspension of activity occurs unless the plant is permanently injured. Gaseous poisons such as sulphur dioxide, ammonia, formalin, and hydrogen sulphide have the same effect on movement of the living plant, when introduced under a bell jar, as have ether and chloroform. In low concentrations response is normal, and activity is suspended only when permanent injury has been inflicted. Temporary suspension of activity can only be induced by placing the plant under conditions unfavourable to its normal metabolism. Absence of light or of oxygen may do this. The stimulation which has been reported from the effects of low concentrations of ether and chloroform by such workers as Thoday[2], Irving[3], Haas[4], and others has not upset the co-ordination of metabolic processes; irregularities are produced when the action becomes irreversible, or, in other words, when permanent injury has been produced. When portions of the stem with the leaf attached are immersed in ether solution the rate of bending is proportional to the concentration of the solution, and until the petiole is fully depressed the pulvinus retains the power of movement, when stimulated by heat, through the remainder of the arc. The pulvinus behaves in the same way towards lipoid solvents. Enzyme poisons react differently, and movement is not directly connected with enzyme destruction, though naturally affected by it as by any other effect on the plant's health. It was concluded that the effects of ether and chloroform on the movement of *Mimosa pudica* were the result of the lipoid solvent properties of these substances.

The action of alcohol, which is a mild animal anæsthetic, is complicated by the fact that it prevents movement after a time by coagulating protoplasm. The present paper is largely an attempt to elucidate the behaviour of the pulvinus of *Mimosa pudica* towards this reagent.

The work of W. H. Brown[5] in 1912 drew attention to the fact that pulvini, which had remained erect after having been killed by heat, curved when subsequently passed through various grades of alcohol and finally to xylol. This was interpreted as being the result of the artificial change of osmotic pressure induced by the treatment. The suggestion has been made that this movement is closely connected with dehydration phenomena. In my former paper the re-erection of petioles dehydrated by alcohol was contrasted with the permanent bending of those treated with ether (p. 138). The re-erection of petioles relaxed by dehydration with alcohol was regarded as a point, though not the main one, in support of the idea of the lipoid solvent action of ether and chloroform as the important factor in their effect on movement. It is necessary therefore to determine whether the depression and re-erection observed during the treatment with alcohol and subsequently with water are due to an osmotic effect or not. In this paper it is proposed to deal also with the effects of coagulation on movement of the pulvini.

Material was obtained from strongly growing plants raised in the open in Brisbane, and consisted of short pieces of stem, each with a petiole attached, the pinnæ having been removed in each case. As a large number of plants had been raised for the purpose, each experiment was repeated at least twenty times, and the material used was as uniform as possible with regard to health and age. Young and old leaves were discarded. It was not possible to use throughout the work leaves whose petioles made the same angle with the stem, as this angle varies greatly according to the position of the leaf on the stem, the angle of the stem (which is straggling), and the surroundings.

It was pointed out in the last paper that this stem-petiole material when allowed to erect in water or in a moist atmosphere shows a sudden and characteristic movement at or about 67 deg. C., the temperature varying slightly with different specimens. The petiole suddenly becomes depressed, and after describing the full arc suddenly returns through an arc of 5 deg. or 10 deg. After this no more movement is possible. The power of re-erection is permanently lost. The double movement is interpreted as a heat response followed by a coagulation of the protoplasm of so many of the cells that a return movement is produced. The movement cannot be the result of shock caused by difference of temperature, as in the experiment this was raised slowly enough to preclude such a possibility. The coagulation of some of the cells at this point is apparently the cause of internal movements which are a sufficient stimulus to cause a response before coagulation has proceeded to such a degree as to prevent it, and the subsequent return then follows. A microscopical examination before and after heating in water to the reaction point shows that coagulation of a large number of the cells does actually take place at this temperature. The protoplast in such cells is dark, shrunken, and granular.

As the contraction of the cells of the lower half of the pulvinus is responsible for the first bending, any further contraction due to coagulation should produce more contraction in the convex half than in the already contracted concave half, thus producing a return movement. If this theory is correct the removal of one half of the pulvinus and subsequent heat treatment should result in a single movement with no return. A number of pulvini were therefore treated by the excision of the upper half, others having the lower half removed. The former responded, as was to be expected, by bending downwards, the latter by bending upwards. On immersion in water a recovery took place, those specimens with the upper half of the pulvinus removed erecting their petioles through a considerably greater angle than was possible with the intact material. In some cases the upward bending was so pronounced that the petiole was reflexed to an angle of —30 deg. with the stem. Recovery of material in which the lower half of the pulvinus had been removed involved a depression of the petiole. (This behaviour is well known and has been described in various papers by Bose; the responses of the upper half and the lower half to electrical stimulus have been investigated by Bose and Das[6], who find that the response to stimulus of the upper half, which is antagonistic to that of the lower half, is very sluggish.) Preparations were gradually heated in water, and it was found that although the petioles had in water at 25 deg. C. reached a certain angle and remained stationary there, they moved slowly to a somewhat greater amplitude as the temperature was gradually raised. This should be expected as the result of heating. The amplitude increased until at the temperature of 67 deg. there was a sudden return upwards where the under half of the pulvinus had been removed, and downwards where the upper half had been removed.

As in the case with all these experiments, the actual angles before and after treatment varied considerably according to the position of the leaf on the branch, the angle of the branch on the plant, and to the direction of lighting of the plant. The following examples are typical when allowance for these factors has been made:—

Experiment 1—

Original angle of petiole with stem of the plant, 100 deg.

Angle after removal of upper half of pulvinus, and recovery in water at 25 deg. C., 0 deg.

Angle after slow raising of the temperature to 65 deg., —15 deg. (reflexed).

Angle after the bending at 67 deg., 45 deg.

There was no return movement.

Experiment 2—

Original angle of petiole with stem of the plant, 100 deg.

Angle after removal of lower half of the pulvinus and recovery in water at 25 deg. C., 130 deg.

Angle after the bending at 67 deg. C., 80 deg.

There was no further return movement.

It was impossible to test the effect of heat on relaxed pulvini immediately after the excision of one half of the pulvinus in order to study the simple contraction due to coagulation. When such pulvini are placed in water their recovery is extremely rapid. The following gives an indication of the speed of the movement:—

Experiment 3.—Rate of recovery in water at 25 deg. C. of pulvini with the lower half removed—

Angle of petiole with intact pulvinus after stimulation, 130 deg.

Angle of same petiole after removal of lower half of pulvinus, 110 deg.

Angle after immersion in water, 30 deg.

Time, 20 seconds.

Experiment 4.—Rate of recovery in water at 25 deg. C. of pulvini with the upper half removed—

Angle of petiole with intact pulvinus after stimulation, 45 deg.

Angle of petiole with upper half of pulvinus removed, 50 deg.

Angle after immersion in water, 45 deg.

Time, 20 seconds.

These rates may be compared with the normal rate of recovery of an intact specimen when placed in water. This, at a temperature of 25 deg., is usually about 21 minutes. The effect of most reagents tried was greatly accelerated by removal of part of the pulvinus. For example, it was found that coagulation by alcohol was effected in quarter the time if part of the pulvinus was removed. The behaviour in water of dissected material opens up an interesting phase of the subject of response. The 20-second response indicates that the reappearance of osmotic substances in the cell is very rapid indeed after the excitatory response. A pulvinus in which thin slices have been removed from the sides but not from the top or the bottom shows the same rapid response, about 20 seconds being the time involved instead of the normal 21 minutes. The significance of this will be discussed at the end of the paper.

Experiments 1 and 2 show that the double movement of the intact erect pulvinus heated to about 67 deg. C. is actually due to the differential response of the upper and lower halves. When one half is removed and the remainder given the heat treatment, only a single movement is produced. In the intact pulvinus the response at 67 deg. followed by the slight return movement may be interpreted, therefore, as the normal shock response caused by commencement of coagulation in the tissues, followed by more or less complete coagulation which produces the return movement, the opposition of the lower and upper halves being responsible for its relatively small amplitude.

Effects of Alcohol.—The effects of alcohol on the pulvini were studied, making use of the movement which has been described above.

Since the ultimate effect of alcohol on the protoplast is coagulation, as pointed out by Seifriz[7] in the case of *Elodea,* it was first necessary to determine the time taken for this to take place to a sufficient extent to interfere with the experimental procedure.

Experiment 5.—Coagulation in intact pulvini by alcohol:—

A large number of pieces of stem-petiole preparations were placed in alsolute alcohol and at intervals of 10 minutes a few withdrawn and placed in water for 10 minutes. They were then gradually heated to 67 deg. It was found that 20 minutes in absolute alcohol did not prevent their re-erection after dehydration but that after 30 minutes some effect could be noticed, and after 110 minutes coagulation prevented any movement except in a few cases. After this time there was no re-erection on immersion in water or change on heating to 67 deg. Below that there was re-erection, and at 67 deg. a return movement; the amount depended on the length of time that the material had been in the alcohol.

Microscopic examination confirmed the assumption that coagulation had occurred, and the similarity of angle of pulvini after heat treatment and after alcohol treatment may be regarded as supporting evidence.

Experiment 6.—Coagulation by alcohol in pulvini with one half removed:—

A similar experiment was carried out with two sets of material, in one the lower half, and in the other the upper half of the pulvinus being removed. After seven minutes coagulation prevented any further movement in most of the pulvini, either in response to immersion in water or to heat treatment after immersion in water, though a few still reacted slightly. The average angle of pulvini with the upper surface removed was, after seven minutes in absolute alcohol, about 30 deg., and of those with the lower surface removed, about 130 deg.

Here we have another example of the shortening of the reaction time by the removal of part of the pulvinus.

The effects of alcohol in coagulating the protoplast having been ascertained, experiments on its effects as a dehydrating agent could be undertaken with precautions to guard against this source of error. It is evident that pulvini from which one half has been excised could not be used in experiments involving dehydration because of the rapidity of coagulation.

First, the effects on erect and on relaxed material were determined.

Experiment 7.—Portions of stem-petiole material were placed in absolute alcohol immediately after their amputation. Their angles were measured before and after dehydration. A typical case was as follows:—

Angle of depressed petiole, 80 deg.

Angle after dehydration, 80 deg.

Angle after transfer to water for one hour, 80 deg.

These results may be contrasted with the following:—

Experiment 8.—Portions of the erect material were placed in alcohol—

Angle of erect petiole, 70 deg.

Angle after dehydration, 95 deg.

Angle after transfer to water for one hour, 70 deg.

These experiments being carried out under similar conditions and large numbers of specimens being employed, the possibility of the difference in behaviour being due to coagulation in the case of Experiment 7 is out of the question. The different behaviour is readily explained by the fact that one experiment started with pulvini whose cells possessed their full osmotic pressure, while the other started with those whose turgor had been lost. If the re-erection of the dehydrated material on treatment with water were due to osmotic absorption these would be the expected results. If this re-erection were due to the dehydration of the tissues, other than by osmosis, even in part, some re-erection should have been observed in Experiment 7. Such was not the case, and it must be concluded that this artificially produced movement is essentially an osmotic one.

Effect of Ether.—Further experiments on material treated as in the last experiment (Experiment 8) were carried out to lend further support to this idea.

Experiment 9.—Erected material was dehydrated in absolute alcohol and the petioles became depressed. They were then removed to a 5 per cent. solution of ether. No re-erection took place.

Experiment 10.—A modification of the last experiment was tried. Erected material was placed in a mixture of equal parts of alcohol and ether. A fall of the petiole took place, and on transference to water at the completion of the depression no re-erection took place. Similar results are produced by substituting benzene or chloroform for ether.

In these cases the only difference in experimental procedure was the treatment of the material with ether (or in confirmatory experiments with benzene or chloroform). The difference in results was the failure to re-erect. Here then is further support for the theory of the osmotic behaviour of dehydrated pulvini.

Erected material was placed in a 5 per cent. solution of ether. In one series of experiments the upper half of the pulvinus, and in the other the lower half, was removed.

Experiment 11.—Erect pulvini placed in 5 per cent. ether solution; upper half of pulvinus removed. In a typical example the pulvinus was sharply turned back, the petiole making an angle of —60 deg. with the stem. After one hour in the ether solution (to ensure the maximum effect) the angle was —5 deg., showing a movement of 55 deg. On transference to water no re-erection took place. On warming there was no action until at about 67 deg., the petiole subsided slowly to 20 deg., a fall of 25 deg. This behaviour was characteristic, though of course amplitudes varied with different specimens.

Experiment 12.—Erect pulvini with the lower half of the pulvinus removed were placed in a 5 per cent. solution of ether. The following was the behaviour of a typical sample:—The angle of the turgid material with the stem was 135 deg. The petiole was depressed. After ether treatment for one hour it had risen to 90 deg., and on transference to water showed no further movement. It was then heated in water, and rose to an angle of 75 deg.—*i.e.*, the petiole rose through 15 deg. Other specimens behaved similarly except for amplitude.

Pulvini were now given similar treatment when in the fully contracted condition.

Experiment 13.—Material with the upper half of the pulvinus removed was immersed in 5 per cent. ether solution for one hour in the fully contracted condition. The following are the measurements of a typical specimen:—

Angle before ether treatment, 60 deg.

Angle after one hour in ether solution, 60 deg.

Angle after hot water treatment, 50 deg.

There was an erection of 10 deg. in this particular case.

Experiment 14.—Material with the lower half of the pulvinus removed while in the fully contracted condition was immersed in 5 per cent. ether for one hour. The following are the measurements of a typical specimen:—

Angle before ether treatment, 100 deg.

Angle after one hour in ether solution, 100 deg.

Angle after hot water treatment, 85 deg.

There was an erection of 15 deg.

From these four experiments (11, 12, 13, and 14) it is seen that the original turgidity of the material has no effect on the final result when the tissue is treated with ether. This is as would be expected if ether destroys the osmotic character of the protoplast. The erect pulvini after treatment by this method lose their turgidity, and, this effected, their subsequent behaviour on the application of heat is the same as that of the originally contracted pulvini. The effect of ether does not interfere with the coagulation movement which naturally is upwards in specimens in which the lower half of the pulvinus has been removed, and downwards where the upper half has been excised.

Discussion.

The work of Blackman and Paine[8] indicates that the loss of turgor in the cells of the pulvinus of *Mimosa pudica* cannot be explained by a sudden increase of the permeability of tissues allowing the rapid exosmosis of dissolved substances. The conductivity method used by these investigators showed that loss of turgor was due to the inactivation of a considerable part of the osmotic substances of the cells. Brown's work (*loc. cit.*), which had been published some six years before, had been an attempt at the artificial lowering of osmotic pressure in the cells by dehydration, and was successful inasmuch as a contraction of the pulvinus was produced. The experiments described in this paper confirm Brown's conclusions, and show that the movement during dehydration and subsequent re-erection when the pulvini are transferred to water is actually dependent on the change of osmotic conditions. When erected material is dehydrated a curvature takes place, and re-erection is possible when the material is replaced in water. When material in which the pulvini are in the relaxed state is dehydrated and then transferred to water, no re-erection takes place; if the bending were a simple dehydration phenomenon independent of osmotic changes, or partly so, a re-erection at least in some degree should be observed. The alteration of the permeability of the protoplasmic membrane by treatment with lipoid solvents prevents a re-erection of material which, orginally in the erect condition, has been dehydrated in alcohol. From these two points of attack, therefore, support has been given to the view that the movement induced by dehydration is an osmotic phenomenon. Sen[9] concludes from his work on the electrical resistance of living tissue that the loss of turgor in stimulated plant tissue is brought about by the induced permeability of the cell membrane. He points out that, as Blackman and Paine admit, non-electrolytes form a considerable portion of the osmotically active substances within the cell, and that the amplitude of response of the leaf of *Mimosa* closely corresponds with the diminution of resistance of the pulvinus. In view of the small amount of the exosmosed electrolytes, however, it seems unwarranted to assume, without definite proof, a sufficient exosmosis of non-electrolytes to cause the movement.

As has been shown in this paper, the sudden fall of a leaf on stimulation is followed by an immediate very rapid recovery if part of the pulvinus is removed. Re-erection is about sixty times as rapid in such a specimen as that in intact material if water is available. If it is not available, recovery does not take place, but a cut pulvinus still relaxed after some time in air, becomes turgid again in twenty seconds when replaced in water. The relatively slow recovery in water when intact material is used is not due to the opposition of the movements of the two halves. If portions of the tissue on either *side* of the pulvinus are removed and the stimulated material placed in water, re-erection takes place in twenty seconds, as it does when top or bottom halves are removed. This rapid recovery explains why Hilburg's plasmolytic investigations revealed no decrease in osmotic pressure in stimulated pulvini. The slow return of the intact pulvinus to the turgid condition, and the rapid return of a pulvinus in which some of the surface tissue has been removed, indicates that the difference is due to the amount of water available. The recovery of potential osmotic pressure in stimulated pulvinar cells is therefore extremely rapid and is not to be gauged by the rate of movement of recovery in the uncut organ. Such behaviour makes it still more difficult to accept the theory of a sudden increase of permeability in the protoplasmic membrane on stimulation. These experiments show that if such were the case it must be followed almost immediately by a sudden decrease, and the reabsorption of escaped substances at such a rate is unlikely. Further, in the sliced material escape into the water in which it is immersed would be rapid, and would not permit of the repeated response observed when such material is subjected to shock time after time.

The effect of alcohol on the movements of the pulvini also lends support to the contention that the contraction is due to the inactivation of osmotic substances rather than a sudden increase in permeability of the protoplasmic membrane.

The failure of re-erection on the part of dehydrated pulvini, which, before the alcohol treatment were erect, when they are treated with ether is explained as due to the lipoid solvent action of this reagent which has been discussed in the previous paper (*loc. cit.*)*. Whether pulvini are contracted or erect, the final angle is the same after ether treatment, which indicates that their osmotic conditions are the same.

The establishment of these points in conjunction with the evidence formerly presented is advanced as support for the statement that the action of ether and chloroform (which behaves similarly in this respect) on the movement of *Mimosa pudica* is essentially the action of lipoid solvents.

Summary.

1. When pulvini of *Mimosa pudica* are heated in water, a sudden contraction, followed by a slight return movement through about 10 deg., takes place when the temperature reaches approximately 67 deg. C. Evidence is presented that the return movement is due to coagulation which takes place in both halves of the pulvinus, but which, because the lower half is already contracted, is more noticeable in the upper half.

2. When a contracted pulvinus from which part has been excised is placed in water, recovery takes place in 20 seconds; the uncut pulvinus requires about 21 minutes under similar conditions. From this it is deduced that the recovery of potential osmotic pressure is much more rapid than would be expected from a consideration of the rate of recovery of an uncut pulvinus.

3. Pulvini treated with absolute alcohol show the commencement of coagulation after 30 minutes, and after 110 minutes only an occasional specimen showed any response. Pulvini from which portion had been excised were usually prevented from showing any movement after seven minutes.

4. The action of alcohol on the pulvini is to cause a contraction which is due to reduction in osmotic pressure. The dehydration of pulvini which are already contracted, if followed by transfer to water, does not result in any erection as would be the case if movement were

* A full statement of the case in support of the view of the regulatory action of lipoids on the passage of material into and out of cells has recently been presented by MacDougall[10].

due to simple swelling, whereas similar treatment of originally turgid pulvini results in re-erection.

5. The treatment of such material with ether prevents any such re-erection. This is interpreted as evidence in support of the lipoid solvent action of ether on the protoplasmic membrane, similar results being produced by the use of chloroform or benzene.

6. The treatment of living pulvini with ether solution produces a final angle which is the same whether the pulvini were originally turgid or contracted.

BIBLIOGRAPHY.

1. Herbert, D. A.—Movement of *Mimosa pudica* as affected by Anæsthetics and other Substances. Proc. Roy. Soc. Q. 37 (7), 121-147, 1925.

2. Thoday, D.—On the Effect of Chloroform on the Respiratory Exchanges of Leaves. Ann. Bot. 27; 697-717, 1913.

3. Irving, Annie A.—The Effect of Chloroform on Respiration and Assimilation. Ann. Bot. 100; 1077-1099, 1911.

4. Haas, A. R. C.—Anæsthesia and Respiration. Science N.S. 46; 462-464, 1917.

5. Brown, W. H.—The Mechanism of Curvature of the Pulvini of *Mimosa pudica*. Philippine Jour. Sc. 7C.; 37-40, 1912.

6. Bose, J. C., and Das, S. C.—Physiological Investigations with Petiole-Pulvinus Preparations of *Mimosa pudica*. Proc. Roy. Soc. B. 89 (B. 164); 213-231; 1916.

7. Seifriz, William.—Observations on the Reaction of Protoplasm to Some Reagents. Ann. Bot. 37; 489-509, 1923.

8. Blackman, V. H., and Paine S. G.—Studies on the Permeability of the Pulvinus of *Mimosa pudica*. Ann. Bot. 32; 69-85, 1918.

9. Sen, B.—On the Relation between Permeability Variation and Plant Movements. Proc. Roy. Soc. B. 94 (B. 660); 216-231, 1923.

10. MacDougall, D. T.—Substances Regulating the Passage of Material into and out of Plant Cells: the Lipoids. Proc. Amer. Phil. Soc. 67 (1), 33-45, 1928.

Chemical Constituents of the Bark of *Melicope erythrococca.*

By T. G. H. JONES, D.Sc., and M. WHITE, M.Sc.

(*Tabled before the Royal Society of Queensland, 28th October, 1929.*)

Melicope erythrococca is a medium-sized tree native of Northern New South Wales and South-Eastern Queensland. In the latter State it is most abundant in the drier type of scrub or rain forest, such as occurs in the neighbourhood of Toowoomba, Nanango, Yarraman, Kilkivan, Burnett River, &c.

The bark of the tree is rough, thick, and of greyish colour, and is possessed of a characteristic and somewhat penetrating odour. Our attention was drawn to the necessity of an investigation of this bark by the Forestry Department, Brisbane, on account of reports received of irritating effects produced on the eyes of axemen cutting the trees and of the peculiar tingling sensation produced by the bark on the tongue, accompanied by stimulation of the salivary flow. It may be noted that this latter feature had formerly been commented on by Mr. H. Tryon, who considered it worthy of the attention of the medical faculty.

Examination of bark supplied from Yarraman, by Forestry officials, has resulted in the isolation of elimicin as principal constituent (90 per cent.) of the essential oil contained in the bark, to the extent of about ·8 per cent. in young trees, with lesser amounts in older trees.

The effects noted above seem to be due to the presence of this constituent, as it is much more pronounced with the free substance than with the original bark and is also possessed by elimicin obtained from another source. No other constituent of the essential oil could be isolated and characterised.

The bark also contains as an important constituent a crystalline substance which is identical with lupeol, an alcoholic body isolated by other investigators from the peelings of lupin seeds,[1] the bark of *Soucheria griffithiana*,[2] gutta percha,[3] and apparently of wide distribution. Although conflicting statements regarding its composition and derivatives appear in the literature, the later investigations of Cohen[4] have resulted in more accurate knowledge. This author concludes that lupeol is a mixture of two substances of molecular composition $C_{31}H_{50}O$. Our results confirm most of the data obtained by Cohen, except the molecular composition, which we believe is more accurately represented by the formula $C_{30}H_{50}O$, isomeric with the amyrins[5], the specific colour reactions of which are also given by lupeol.

Experimental.

In our examination of the bark, attempts to remove the essential oil by steam distillation resulted only in imperfect separation, and we have made use of percolation methods, using ether as a solvent on the small scale and light petroleum with larger amounts of bark.

Ten pounds of finely-ground bark on extraction with ether gave, after removal of ether and distillation of the residue *in vacuo* with glycerine, 38 ccs. [·8 per cent.] of oil with the following constants:—

$d_{15 \cdot 5}$	1·0343
n^{20}_{D}	1·501
$[\alpha]$ D	1·4
Acid value	nil
Acetyl value	nil
Ester value	29

Fractionation of 35 ccs. of the oil at 30 mms. pressure resulted in the isolation of 30 ccs. of a fraction b.p. 180° C. with a small lower fraction 2 ccs.

For the large fraction (30 ccs.) the following constants were obtained:—

$d_{15 \cdot 5}$	1·068
n^{20}_{D}	1·5280

These constants suggested elimicin, which was confirmed by the following experiments:—

(*a*) Combustion results—
Found C 69·5 per cent. H 7·7 per cent.
$C_{12}H_{16}O_3$ (elimicin) requires C, 69·2 H 7;

(*b*) Methoxy determination—
·2574 grs. gave ·7748 grammes AgI, indicating three methoxyl groups.

(*c*) Oxidation with potassium permanganate in alkaline solution gave trimethyl gallic acid M.P. 169° C.

(*d*) Conversion to iso-elimicin by boiling with sodium ethoxide solution, from which was prepared iso-elimicin dibromide M.P. 88° C.

Isolation of Lupeol.—As the residue left after removal of the elimicin from the ether extract, in the experiment recorded above, gave indications of the presence of a crystalline substance, larger quantities of bark (60 lb.) were crushed and repeatedly extracted by percolation with low-boiling petroleum ether. The greater portion of the solvent was removed by distillation, resulting in the deposition of considerable quantities of semi-solid material, which was separated as far as possible from the oily liquor containing the essential oil [70 ccs. elimicin were obtained from this oil].

The semi-solid material—from which on the small scale crystals of lupeol could eventually be obtained by draining on a porous tile and recrystallisation of the resulting solid*—was boiled under reflux with alcoholic sodium hydroxide to hydrolyse fats and esters and the lupeol extracted with petroleum ether.

After this treatment the lupeol could be readily crystallised from alcohol and, after purification, needle-shaped crystals were obtained M.P. 212° C. Yield of purified lupeol 52 grammes.

Combustion results—

Found C = 84·3 H 11·6.

$C_{30}H_{50}O$ requires C 84·5 H 11·7.

Lupeol acetate, prepared by acetylation, melted at 214° C. The acetyl value was 120.

Lupeol regenerated from the acetate melted at 212° C.

Lupeol benzoate, prepared by benzoylation, melted at 264° C.

Lupeol phenyl carbimide, prepared by the action of phenyl isocyanate, melted at 226° C.

Lupeol Bromo Acetates.—Two mono-bromo acetates were obtained by adding bromine in carbon tetrachloride to lupeol acetate in the same solvent.

Separation was effected by fractional crystallisation from alcohol.

The more sparingly soluble bromo-acetate separated in crystalline plates, and melted at 204° C, and contained 14·7 per cent. of bromine.

The second bromo-acetate (crystalline needles), more soluble in alcohol, and therefore not as readily purified, contained 16·6 per cent. of bromine, and melted at 166-168° C. Recovery of the acetates from their bromo derivates by reduction with zinc dust and glacial acetic acid gave two acetates of M.P. 214° C and 156° C respectively. From the former of these—that is, from the least soluble bromo-acetate, and obtainable in sufficient amount, the lupeol was recovered by hydrolysis. The melting point was 211° C, and on analysis gave results in agreement with the formula $C_{30}H_{50}O$.

We were unable to obtain sufficient pure alcohol from the second bromo-acetate for analysis, but the percentage of bromine would indicate a different molecular composition from $C_{30}H_{50}O$.

Lupeol bromo-benzoate.—This was prepared in similar manner to the bromo-acetate, and the sparingly soluble bromo-benzoate [Br = 12·7

* Crystals so obtained possessed specific rotation $[\alpha]D = + 31·4$. The bulk of our material, obtained after hydrolysis of fats, was inactive, and therefore racemised during the hydrolysis.

per cent.], recrystallised from acetone and then from ethyl-acetate, melted at 240° C. Our supplies of material were inadequate for definite isolation of the second bromo-benzoate analogous to the second bromo-acetate.

These results are in substantial agreement with those of Cohen, and confirm his view that lupeol is a mixture of two substances, one, however, apparently present to a much greater extent than the other.

REFERENCES.

1. Likiernik Zeit. Physiol. Chem. 1891, 15, 415.

2. Sack and Tollens, Ber. 1904, 37, 4110.

3. Van Romburgh Abstr. Chem. Soc. 1906, 1, 20, Jungfleisch and Leroux, Compt. rendu. 1907, 144, 1435.

4. Abstr. Chem. Soc. 1907 I., 211.

5. Jungfleisch and Leroux also expressed this view.

Cyttaria septentrionalis, a New Fungus attacking *Nothofagus Moorei* in Queensland and New South Wales.

By D. A. Herbert, D.Sc.,

(Department of Biology, University of Queensland).

Plate XI.

(*Read before the Royal Society of Queensland, 25th November, 1929.*)

The genus *Cyttaria* comprises five recognised species parasitic on the Beeches (*Nothofagus* spp.) of South America, New Zealand, and Australia.[1] *C. Gunnii* Berk. occurs in Tasmania on *Nothofagus Cunninghamii,* but not on *N. Gunnii.* McAlpine[2] records it from Victoria from the former species. It is reported by Simpson and Thompson[3] as the greatest opponent of the forest growth of *Nothofagus Menziesii* in New Zealand. *C. Purdiei* Buchanan, described from *N. fusca* in New Zealand, is regarded as belonging to *C. Gunnii.* Buchanan's description is very brief and inadequate, but his illustration shows that this species was almost certainly the one described by Berkeley from Tasmania thirty-seven years before. *C. Berterii* Berk. attacks *N. obliqua* in Tierra del Fuego, Patagonia, and Chile; *C. Darwinii* Berk. attacks *N. antarctica* and *N. betuloides* in Tierra del Fuego, Patagonia, and Chile; *C. Harioti* Fischer is found on *N. betuloides* and *N. antarctica* in Tierra del Fuego; and *C. Hookeri* Berk. occurs on the branches of *N. obliqua* and *N. antarctica* in Tierra del Fuego, Patagonia, and Hermit Island, Cape Horn. *C. disciformis* Lev., a tremelloid fungus found in dead bark in Chile, is not regarded as a Cyttaria.

Of the twenty-one species of *Nothofagus* recognised (under *Fagus*) in the Index Kewensis, eleven are South American, seven New Zealand, and three Australian species. There are in addition a number of hybrids described from New Zealand.

Cyttaria is confined to the genus *Nothofagus,* but, as the records show, more than one species of beech may be attacked by the same species of fungus; while the same beech may be parasitised by more than one species of *Cyttaria.* The wide range of *Cyttaria* and its occurrence on different host species raised the question as to its possible occurrence in New South Wales or in Queensland on the northernmost of the southern beeches—*Nothofagus Moorei.* This species occurs in Queensland on the higher levels of the McPherson Range at an altitude of approximately 3,000 feet from sea level, and also in various localities in New South Wales as far south as the Gloucester River.

An unsuccessful search was made in May, 1928, for *Cyttaria* in the beech forest of Roberts Plateau, but the O'Reilly brothers, residents of the Plateau, from a description of the Tasmanian species, said that they had at times seen such a fungus near the New South Wales border. In May, 1929, on another visit to the area, a number of the typical galls, similar to those found on *N. Cunninghamii* when it is attacked by *Cyttaria Gunnii,* were collected, and the O'Reilly brothers reported that two of the fruiting bodies had been brought back from the border in November by a visitor, but had unfortunately been lost. There seemed little doubt, therefore, that *Cyttaria* was to be found in Queensland on *N. Moorei.* Mr. C. T. White, F.L.S., Government Botanist, at the beginning of September, 1929, while visiting Mount Hobwee, about 14 miles south of Beechmont and on the New South Wales border, obtained young stromata of a typical Cyttaria. These were already the size of *C. Gunnii* but were far from mature, the cover layer of the apothecia being intact and the asci undeveloped. On 17th September, therefore, the same locality was visited by the writer, and by that time it was possible to obtain a satisfactory amount of mature material.

Mount Hobwee is on the border of Queensland and New South Wales, at the eastern end of the Queensland National Park. It reaches an altitude of 3,580 feet. The Cyttaria was collected both sides of the border. Only a few acres of beeches were attacked on Mount Hobwee, and those near the summit. The moss-hung branches and the general character of this patch seemed to indicate that the cloud-belt was the important factor in the localisation of the fungus. Similar conditions obtain at Mount Wanungra, a few miles west, where the other evidence of the presence of Cyttaria was found.

The name of *Cyttaria septentrionalis* is proposed for the new species, on account of its being the northernmost member of the genus. The description is as follows:—

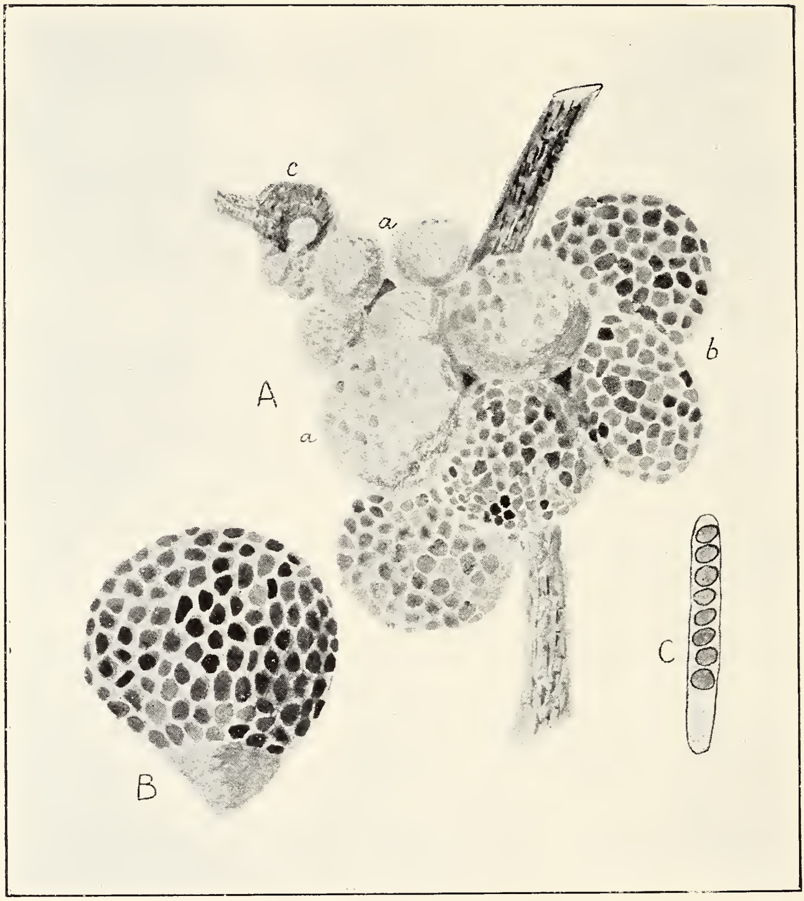
Cyttaria septentrionalis sp. nov.—stromata gregaria, globosa, 5-7 cm. diam., demum cava, superficie ubique locellata, flava; locellis 3 mm. latis; ascis cylindraceis 170-210 μ longis, 17 μ latis, octosporis, non stipitatis; sporidiis globosis, 15 μ diam., paraphysibus filiformibus; species edulis. Hab. in summo monte Hobwee, ad ramos vivos *Nothofagi Moorei,* Sep. 1929.

The new species is distinguished immediately from the other Australian species, *C. Gunnii,* by the size of its fruits. The stromata are produced in clusters of varying numbers, sometimes a hundred or more, on characteristic swellings on the attacked branches. Usually the smaller branches are affected and the cluster may encircle it. In larger branches it may be lateral. The stromata in a typical cluster may be in all stages from small round parchment-coloured objects; a millimetre or so in diameter, up to the fully grown structures 7 or 8 centimetres across. When not crowded they remain globular, but usually through mutual pressure they necessarily become pyriform. In the early stages they are homogeneous throughout, but are at length hollow, to a slight extent from a gelification of the interior but mainly owing to the growth of the peripheral layers. The inner surface of the mature fructification is regularly verrucose, each prominence representing an apothecium. When they have attained the diameter of approximately 1 centimetre, a regular reticulate pattern is apparent on the surface. Later, dehiscence takes place and the apothecia are exposed. These are rather angular in outline, yellow, and usually 3 millimetres across. The apothecia cover the stromata except for a small portion of the base; those at the apex are the first to dehisce. The sterile basal region is much smaller comparatively than that of *C. Gunnii.* The asci are 170-210 micra in length, 17 micra in breadth, and eight-spored, the ascospores globular and 15 micra in diameter. The paraphyses are filiform. The mature stromata are somewhat gelatinous and of the consistency of a *Hirneola.* When disturbed they emit a cloud of ascospores. The ground beneath affected beeches is strewn in the season with freshly fallen and decaying *Cyttaria* fruits, which are quite conspicuous on account of their reticulations and the yellow colour.

In a dry atmosphere the stromata become leathery. On Mount Hobwee, however, they remain gelatinous and are forced off by their growing neighbours. Those that do not fall (being held by two or three growing adjacent) rot in the cluster, and the decay spreads to the younger ones, the apothecia of which may not have opened. The fungus responsible is a *Monilia.* It covers the affected fruits with a fine white mass of mycelium, tufted at first, the tufts finally confluent.

The branches of the beech beyond the *Cyttaria* galls are retarded in their growth, and the gall occasionally is at the end of the branch, the distal parts of which have been killed. At other times, though, a number of clusters of the fruits occur along the length of a branch, the general appearance, apart from the galls, is normal. The disease is certainly a serious one, but beeches, whether attacked or unattacked by *Cyttaria,* are almost invariably very decayed, and perfectly sound trees are exceptional.

The previously described species of *Cyttaria* are all edible. Darwin, in his Journal of Researches, described *C. Darwinii* of Tierra del Fuego as being eaten uncooked in its mature state. It has a mucilaginous slightly sweet taste, and a faint smell like that of a mushroom. The



Cyttaria septentrionalis sp. nov. (A) Cluster of stromata on branch of *Nothofagus Moorei:* (*a*) immature; (*b*) mature; (*c*) small gall. (B) Mature stromata. (C) Ascus. (A) Two-thirds natural size; (B) natural size.

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Tasmanian *C. Gunnii* was eaten by the aborigines, and was known to the settlers as tree morell. The Queensland species has practically no taste or smell, but the stromata, especially when immature, are quite palatable.

I am indebted to Mr., Mrs., and Miss Rankine, of Beechmont, for their help in obtaining the material from Mount Hobwee, to Mr. C. T. White, F.L.S., Government Botanist, Queensland, for locating the fungus, and to Mr. Clive Lord, F.L.S., Director of the Tasmanian Museum, for specimens of *C. Gunnii*.

BIBLIOGRAPHY.

1. Saccardo, P. A.: Sylloge fungorum, VIII., 4-7, 1889.
2. McAlpine, D.: Systematic Arrangement of Australian Fungi, Melb., 1895.
3. Simpson, G., & Thompson, J. Scott: On the Occurrence of the Silver Southern Beech (*Nothofagus Menziesii*) in the neighbourhood of Dunedin. Trans. & Proc. N.Z. Inst., LIX., 326-342, 1928.
4. Buchanan, J.: On *Cyttaria Purdiei*. Trans. N.Z. Inst., p. 317, 1885.

The Stratigraphical Relationship of the Shales about Esk to the Sediments of the Ipswich Basin.

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Geological Map and Five Text-figures.

(*Read before the Royal Society of Queensland, 28th October, 1929.*)

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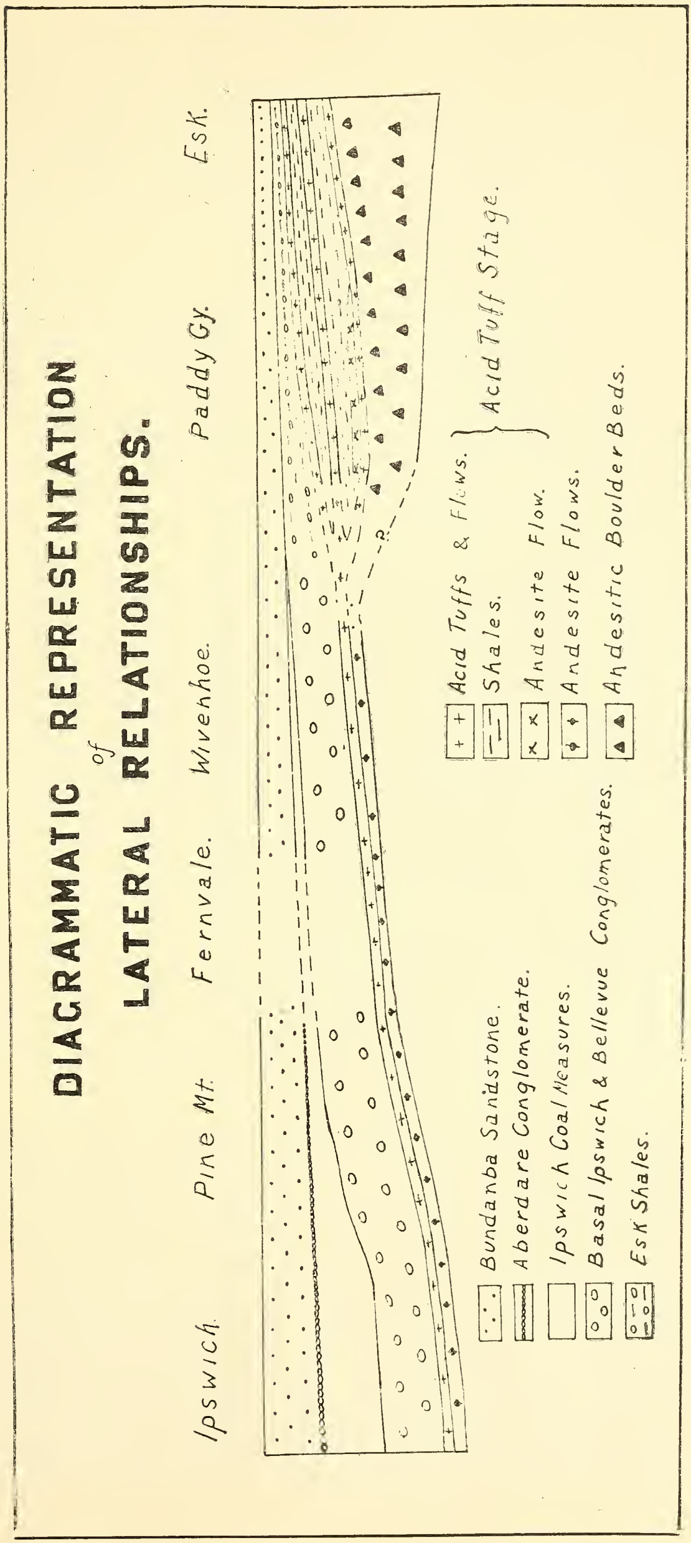
Appendix A.—Bibliography of the Ipswich Coal Measures.
Appendix B.—Bibliography of the Esk Mesozoics.

I.—INTRODUCTION AND OUTLINE OF CONCLUSIONS.

The stratigraphical relationship between the rich plant-bearing Ipswich and Esk series has long been a problem calling for settlement. The two series are geographically close, palæontologically and structurally rather similar, and yet lithologically different.

During the current year the author has been engaged on this fascinating problem and has obtained results indicating that the two series represent closely related phases in a shallow fresh-water basin, with but a slight chronological difference. For in effect the basal conglomerate of the Ipswich series changes laterally into the highest division of the Esk series, the Esk shales. The Ipswich coal measure shales thin out rapidly northward, and are missing from the basin north of Bellevue, where the overlying Bundanba sandstone comes to rest without apparent unconformity on the Esk shales.



TEXT-FIGURE 1.

II.—PREVIOUS WORK.

Very early in the search for deposits of industrial importance in Queensland, coals were discovered in the Ipswich area in 1843[1]. Some time later seams with a rather greater percentage of volatile hydrocarbons were found to the west of Ipswich, at Walloon, and on the Darling Downs. In both localities the seams occurred in a freshwater series of soft sandstones and shales ; consequently, the measures of both districts were written of as one formation—the Ipswich formation.

Gradually the superiority of the coals near Ipswich (due to situation and quantity) became evident, and W. E. Cameron was detailed by the Government to make a geological survey of the Ipswich area. By 1905 he found[2] that the Walloon coals were on a higher horizon in a conformable series than the Ipswich, the two being separated by a barren sandstone stage, the Bundanba sandstone. The Ipswich stage was then divided into two :—(1) a very thick basal conglomerate, and (2) the coal-bearing beds ; these latter were shales, sandy shales, and sandstones with coal seams at various horizons, all beds being markedly lenticular in character.

In 1910[3] Dr. Marks continued Mr. Cameron's work eastward and south-eastward to the coast, and showed that the Mesozoics there were the lateral equivalents of those of the Ipswich basin. He found that no detailed comparison could be made, due to the lenticularity of the basin deposits ; but that there was a division into three major groups equivalent to the Walloon, the Bundanba, and the Ipswich stages. There was no basal conglomerate, but Cameron in 1905 showed that the basal conglomerate along the northern boundary of the field thinned out towards Brisbane. Cameron had mapped[4] at various places, towards the base of the basal Ipswich conglomerate, outcrops of an acid tuff. Dr. Marks mapped in detail a rhyolite tuff taking a definite course through Brisbane and southward, always at the base of the Ipswich beds.

Meanwhile odd coal seams and plants of an Ipswich facies had been reported from round about Esk ; and in 1912 Dr. Marks[5] visited the area to investigate coal prospects. These he reported of no economic value. But he came to the opinion that the age of the beds about Esk was Walloon, due to their geographical position with respect to the Ipswich series.

This, then, was the stratigraphical position when Dr. Walkom[6] studied the collected Lower Mesozoic plant fossils of Queensland, and their literature. The material he worked on was chiefly drawn from the well-known Denmark Hill horizon at the top of the Ipswich coal measures ; but small collections from many other localities of unknown horizon were also examined. Dr. Tillyard[7] studied the insects from Denmark Hill ; and both workers concluded that the Ipswich coal measures were Rhætic or Upper Triassic in age. The plants from about Esk seemed to belong on the whole to genera believed to be characteristic of the Jurassic. Consequently, it was not suspected that the correlation of the shales about Esk with the Walloon series was erroneous. Mr. Cameron was meanwhile still working in the Ipswich field, and in 1922 his latest and most detailed map was published, unfortunately without a report. In this map Mr. Cameron shows that he interprets the structurally complicated West Ipswich area as a N.W.–S.E. faulted anticline.

Two new workers in Messrs. Reid and Morton now entered the field. They followed the vertical strip of rocks in the West Ipswich area north past Pine Mountain to Fairney View. Quite close to this strip only slightly inclined Ipswich or Bundanba strata were to be found ; and the vertical strip seemed to be devoid of the coal seams and shales so characteristic of the horizontal series.

These observations suggested to Messrs. Reid and Morton an interpretation very different from Cameron's West Ipswich fault. They concluded that the vertical beds were an older series on which, after a violent orogeny, the Ipswich coal measures were deposited. Nevertheless, the flora of the vertical beds were all forms found in the Ipswich beds. This vertical strip they called the *Borallon series.* They traced it past Fernvale to Northbrook, where they mapped in the Esk series as unconformable on it.

The publication[8] of their views gave rise to the interesting " Borallon Controversy "[9] which ended by their recognising[10] the vertical strip of " Borallons " as due to the effect on the Mesozoic Ipswich and Esk beds of a very regular and strong folding and faulting movement, running N.N.W. from Beaudesert to Goomeri.

Apart from the recognition of this strong line of movement their work had a distinct value in that the rocks of the Esk area were grouped[11] into an *Esk series* striking N.W. and dipping gently S.W. This, they considered, consisted of three divisions :—

(1) A lowest series of andesitic agglomerates and andesitic flows, conformably overlain by—

(2) The Esk shales and Bellevue conglomerates (lateral equivalents) with interbedded trachyte tuffs.

(3) The Esk trachytes were believed to represent the top of this series. These had earlier been assigned by Dr. Richards[12], from general considerations, to a Tertiary age.

To the west this series was followed by a siliceous sandstone series which Reid and Morton regarded as a continuation of the Bundanba sandstone. They believed this to be separated from the Esk series by a slight unconformity, or at least a disconformity, represented in time by the extrusion of the Esk trachytes.

From stratigraphical considerations they believed the Esk series to be the equivalent of the Ipswich coal measures. This was supported by palæontological considerations. In 1921–1923 Reid noted[13] that the genus *Thinnfeldia* was predominant in the Ipswich series, but did not occur in the Walloon of the type district. Here *Tœniopteris spatulata* was predominant, while it did not occur in the Ipswich coal measures. In their examinations of the Esk flora, Reid and Morton[14] and Walkom [15] found

Thinnfeldia predominant, while *T. spatulata* was absent. Consequently the Esk series was removed from the Walloon and equated to the Ipswich coal measures.

Knowledge of the geology of the Ipswich–Esk area was at this interesting stage when the author began work on it.

III.—PHYSIOGRAPHY.

The present topography of the area under consideration is decided by two factors :—

(1) The structural attitude and differential hardness of the Mesozoics, causing erosion into forms relating to those structures.

(2) The meanderings of the mature Brisbane River.

The effects of (1) are quite simple and obvious ; more so for the Esk series than for the Ipswich, since only in the town of Esk itself, where the country is quite flat, do Tertiary and later deposits obscure it, while many Tertiary and superficial deposits overlie the Ipswich series in the type district.

Just south-east of Esk, the Esk shales outcrop strongly with very slight dips ; and here (Pors. 33, 94, 85, Par. Esk) erosion forms, typical of gently dipping sediments, are noticeable.

South towards Tea Tree Creek the dips are steeper ; with the result that long N.W. ridges due to the superior weathering resisting powers of the trachyte tuffs have been formed, broken only by streams flowing across the strike. Such streams, *e.g.*, Paddy Gully and Tea Tree Creek, would therefore appear to be relics of an earlier system of drainage.

The lowest stage of the Esk series, the andesitic boulder beds, forms gently undulating ground.

Southwards the Esk shales change laterally into the Bellevue conglomerates, and the series becomes almost horizontal, pebbly ridges resulting. A residual capping of Bundanba sandstone forms the high ground of Wivenhoe Hill. East and west of a line from Northbrook to Fairney View there is a remarkable contrast in topography, due to the different weather-resisting powers of the Mesozoics and the schists of the D'Aguilar block. To the west the Mesozoics form low ground showing mature topography, to the east the older schists form highlands exhibiting the young topography of steep rugged hills and deep valleys. The basal Mesozoic andesite and trachytic tuffs form the foot slopes of these schist heights. South of Fairney View these igneous rocks become unimportant topographically, and the heavy basal Ipswich conglomerates form the foothills for the schist highlands along the northern boundary of the Ipswich coalfield. In some places the outline of these conglomerate foothills would suggest that they had been step faulted parallel with the junction with the schist ; but there is as yet no geological confirmation of this.

The Ipswich coal basin itself has almost reached peneplanation.

This peneplanation has removed from view all except very superficial thicknesses of Tertiary sediments and basalts, so that the late Cretaceous or early Tertiary peneplain upon which they were laid down is now visible. Had uplift occurred instead of the downwarp causing this Tertiary sedimentation and consequent protection of the early Tertiary peneplain, it is probable that to-day the early Mesozoic topography would have been visible instead.

The physiography of the Ipswich coal basin is in quite marked contrast to that of the country further away from the schist mass, where erosion did not progress to peneplanation before the extrusion of the Tertiary basalts ; *e.g.*, in the Rosewood–Walloon coalfield, the basalts overlie Walloon sediments and erosion has left them standing as a capping to a young range of plateau type.

The effect of the meandering of the Brisbane River in the present topography, while much more interesting than the first factor, is less important, due to its localisation of action. Odd boulder beds are to be seen at various high levels near the present river, indicating early river beds. Somewhat later courses are to be found in the present alluvial flood plains of the river ; and careful work should result in the collection of enough data for the elucidation of the complete history of the Brisbane River.

It is an imporant fact that the present Brisbane River course in the area examined closely follows the junction of the Mesozoics with the schist ; and the meanderings crossing this junction are of small radius.

IV.—SEQUENCES AND STRUCTURE.

Under this heading it is proposed to describe in geographical order the various sections studied by the author, and to show how they are correlated one with another.

(A) Esk–Paddy Gully Area.

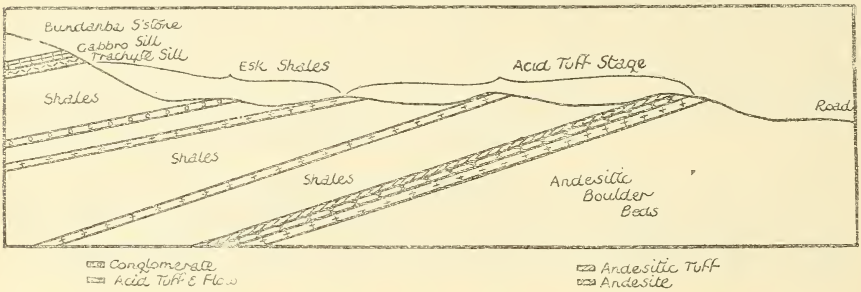
Wherever outcrops are found under the flat alluvial sands on which the town of Esk is built, they are of shales and sandstones rich in fossil plants of a Mesozoic aspect. The general strike of these sediments is N.W. and they dip gently to the S.W. In lithology the beds vary from olive-green shales to fine-grained light-brown sandstones. When weathering *in situ* they become rather like the grey Ipswich shales in colour, but unlike them in texture.

The succession is well seen somewhat to the south-east of Esk (Pors. 33, 94, and 85, Par. Esk). Here they are almost flat (becoming steeper towards the Glen Rock intrusive*) and are capped to the south-west apparently conformably by a coarse red siliceous sandstone believed to be a northerly continuation of the Bundanba sandstone.

* The Glen Rock intrusive and the Esk trachyte and their relations to the Esk sediments are described in the section on Igneous Activity.

The Esk shales are seen to be divided into two by the strong development of a greenish, compact, pebbly sandstone The upper shales are well seen in Por. 94, where they are remarkably fossiliferous*, many undescribed forms occurring. *Schizoneura sp.* is perhaps the most characteristic fossil of this horizon. The pebbly sandstone may be traced with gradually steepening dips to Paddy Gully, where it forms a marked conglomerate horizon. The lower of the two shale horizons gives no good outcrops. It overlies in Por. 85 an important trachyte tuff, which is associated with a fine silky grey shale band characterised by abundant *Ginkgo cf. magnifolia* Fontaine.

This tuff, here forming Wildcat Ridge, was traced continuously in the field to Paddy Gully, where it was possible to make a section across the Esk series by walking along the boundary fence between the parishes of Esk and Wivenhoe. The new post-holes gave good indications of the underlying rocks.



TEXT-FIGURE 2.—SECTION ACROSS HILLS TO SOUTH OF PADDY GULLY.

Nowhere was an outcrop giving the dip found, but in the author's opinion it is about 15° S.W.

The section was begun from the west on the coarse compact red siliceous sandstone believed to be Bundanba. Between this and the Esk series there occurred (on the north bank of the gully) a gabbro sill and a hornblende porphyrite sill†, the gabbro sill being between the Bundanba and the hornblende porphyrite sill.

A small " valley " of greenish shales and soft pebbly sandstones follows the hornblende porphyrite (on the south bank of the gully) and then a low ridge of a hard compact pebbly sandstone, the same horizon as that seen in Pors. 33 and 94, Par. Esk. The next valley between ridges 2 and 3 was due to the softness of a set of shales and sandstones with fine conglomerates. For these parts of the Esk series the author wishes to propose the name *Esk shales*, since, as above described, they form the bedrock of the town of Esk.

* Lists of fossils from these and other localities are given in Section VIII.

† The significance of this post-Bundanba intrusion is referred to in the section on Igneous Activity.

The next ridges, 3, 4, and 5, were due to the hardness of three beds of trachyte tuffs with accompanying trachyte flows, descriptions of which will be found in the section on Igneous Activity. Ridge 3 represents the continuation as traced in the field of the trachytic tuff of Wildcat Ridge (Por. 85) and here again it is associated with *Ginkgo cf. magnifolia* Fontaine.

The valleys between ridges 3 and 4 showed outcrops of soft pebbly sandstones and conglomerates, with interbedded shales.

The slope east down from ridge 4 showed soft conglomerates and sandstones. The slope up to ridge 5, however, showed first an andesitic tuff, then an andesitic flow, and then, forming the crest of the ridge, a strong trachyte flow interbedded with trachytic tuffs.

This part of the section the author proposes to call the *acid tuff stage*.

The section from ridge 5 to the road was over a peculiar stage, called by Reid and Morton an " andesitic agglomerate." The present writer prefers to call it the " *andesitic boulder beds* " since the term agglomerate implies a pyroclastic origin, to demonstrate which there is here no evidence. The andesitic boulder beds consist of boulders of andesite and felspar porphyry only set in a greenish matrix which macroscopically looks tuffaceous, but which has never been found fresh enough to section. The boulders in some localities, *e.g.*, Deep Creek, are nearly all rounded, while in others they are nearly all angular ; the latter occurrence is the more usual. The size of the boulders is on the average 3–6 in., but 3 ft. masses have been seen. The writer has found no interbedded andesitic flows in the material, but at one locality—Deep Creek—she has seen interbedded greenish shales.

To date the author has thought of no reasonable mode of origin for these most peculiar boulder beds, which are believed to represent the base of the Esk series.

The Esk series is now seen to consist of—

- Esk series
  - Esk shales
    - Upper shales
    - Compact pebbly sandstone
    - Lower shales
  - Acid tuff stage
    - Trachytic tuff
    - Shales, sandstones, conglomerate
    - Trachytic tuff
    - Shales, sandstones, conglomerate
    - Andesitic tuff
    - Andesitic flow
    - Trachyte tuff and flow
  - Andesitic boulder beds.

No unconformity is to be found within this series.

(B) Moombra–Bellevue–Wivenhoe Area.

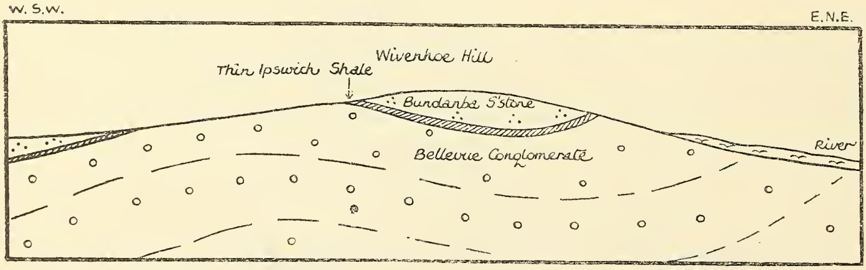
South-east from Paddy Gully the acid tuff stage was traced continuously through Tea Tree Creek to Moombra, where from a shale interbedded with the top tuff an important flora has been collected and has been described by Dr. Walkom[16].

This acid tuff stage was further traced E.S.E. to the Brisbane River; but not across the river. Mr. Morton informs the author that the same tuffs do occur there, however.

The continuity southward of the Esk series has been traced by Messrs. Reid and Morton in 1923 in a more accessible district, and in a more interesting portion of the series, *i.e.*, in the Esk shales; and the field work forms an interesting study in lateral lithological variation.

It has already been noted that the Esk shales were much coarser at Paddy Gully than about Esk. Traced still further to the south-east, they get coarser and coarser as their dips flatten out and the stage thickens, until in the section between the top of the acid tuff stage at Moombra and the Bundanba sandstone to the south they have changed so much lithologically as to warrant a new name for the same stage—*the Bellevue conglomerates*. These consist of shales and sandstones interbedded with beds of coarse conglomerate, the sandstones becoming predominantly of a fine brown felspathic type, although green shale and grit beds are important. The pebble beds are green or grey in colour. The pebbles of this conglomerate are largely of andesites, green cherts, and a grey indurated grit, while jaspers, quartzites, trachytes, and rhyolites are also represented in small numbers. In this section the beds strike N.W. and are almost flat, the dip being about 3° S.W.

Towards Wivenhoe Hill the beds dip from all sides under an outlier of Bundanba sandstone of lithology similar to that already described, but from which they are separated by a slight thickness (50 ft.) of soft shaley sandstones. Fossils have been collected from the top of the Bellevue conglomerates from two horizons at the foot of this outlier of sandstone—one half way up the road on the northern slope of the hill (Por. 42, Par. Wivenhoe) and the other in Sheep Station Creek (Pors. 74 and 36). The writer believes the first of these to be the lower, from structural considerations, although she can produce no direct field evidence.



TEXT-FIGURE 3.—DIAGRAMMATIC SECTION THROUGH WIVENHOE HILL.

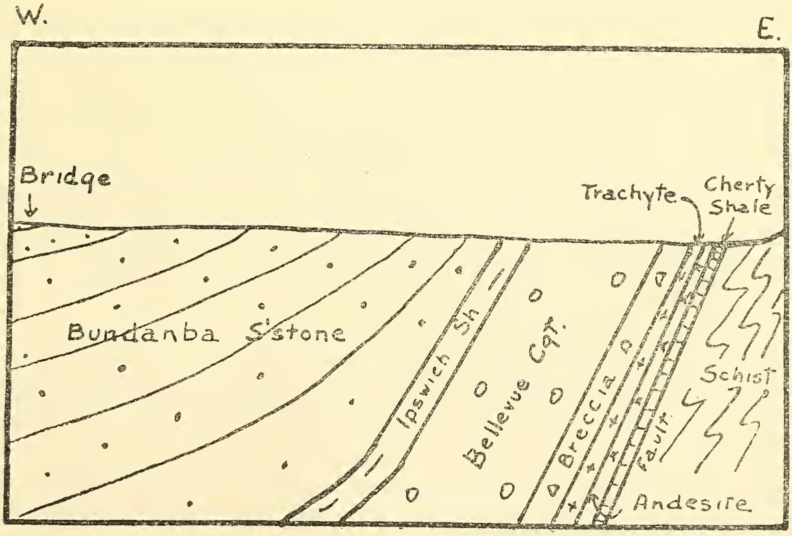
As one approaches the junction with the schist on the east, the proportion of sandstones and shales gets smaller. On the Northbrook reach of the river there are no shales and sandstones of importance, while the pebbles appear to be all either green or grey. The relationship of the Wivenhoe Hill capping of Bundanba sandstone to the underlying Bellevue conglomerates may be seen in Text-figure 3.

(c) Wivenhoe–Fernvale Area.

The Bundanba sandstone capping of Wivenhoe Hill may be traced eastwards along the banks of the Brisbane River past Wivenhoe bridge, and along to the point on Portion 68 where the river turns back on itself. A diagrammatic section showing the relationships from Wivenhoe bridge eastward to the schist is seen in Text-figure 4.

East from Wivenhoe bridge the coarse siliceous current-bedded brown sandstone has gradually steepening dips, till it is about 70°. Then a change in lithology occurs, and soft felspathic shaley sandstones, alternating with shales carrying macerated plant remains and containing a few carbonaceous seams, follow. This finer, softer development would not be more than 200 ft. thick, and the author regards it as the thin northerly development of the *Ipswich coal measure series*, which gradually thins out going north from the Ipswich coal field. These have a dip increasing towards the east from 60°–80°; and they are followed just at the turn in the river by a heavy conglomerate series, the *Bellevue conglomerate* consisting of vertical conglomerates and interbedded greenish shales and grits. One of these fine green shales, in Por. 52, Par. Burnett, was remarkably fossiliferous, and a good collection was made. This shale was almost at the base of the Bellevue conglomerate.

The conglomerate was followed further to the east by about 50 ft. of a breccia in which the fragments were chiefly quartzites which possibly represented a shore line breccia ; then representatives of the acid tuff



Text-figure 4.—Section East from Wivenhoe Bridge.

stage of the Esk series in the shape of trachytes and trachytic tuffs, and an andesite and andesitic tuff were obtained, followed by a fine green cherty shale. This latter seemed in places to be separated from the schist by a peculiar brecciated rock which Mr. Denmead* suggests as a fault breccia. This is followed by the Fernvale series of the Brisbane schists.

All the beds had a constant N.W.–S.E. strike, due to the strong N.W.–S.E. faulting.

Alluvium intervenes between this section and the Fernvale outcrops, nevertheless the lithology of the acid tuff stage leaves no doubt that the series continues to the south-east beneath the alluvium.

(D) FERNVALE–FAIRNEY VIEW BELT.

Geographically, this belt is a connecting link between the areas of outcrop of the type Ipswich and Esk series. It is a narrow N.W.–S.E. striking belt of vertical igneous rocks and interbedded sedimentaries, and has a faulted junction with the schist to the east. This fault is referred to as the Great Moreton fault.

The igneous rocks are acid tuffs, trachytes, and andesites of a type exactly similar to those beneath the Bellevue conglomerates in the Wivenhoe section. They are therefore regarded as the chronological equivalent of the acid tuff stage. Here, however, they do not appear to be associated with conglomerates like those at Wivenhoe or Mt. Crosby. The thin sediments with which they are interbedded are all greenish in colour, being chiefly grits with some fine pebble beds and some shales of so fine a nature that they have been chertified.

This acid tuff stage forms the foothills to the schist highlands ; and it is succeeded immediately to the west, along a line apparently approximately parallel to its junction with the schists, by a low sandy plain derived from the weathering of an underlying sandstone series.

This sandstone series is the Marburg sandstone stage of Mr. Reid[17]. The beds of this stage vary rapidly in lithological character, yellow felspathic and micaceous flagstone types being associated with white very siliceous grits, and with coarse ferruginous sandstones. The strike is N.W. and the dip gently S.W., the maximum dip reading obtained being 15° S.W. on the road west of Portion 176, Parish North. Where this sandstone stage is found in closest association with the acid tuff stage, *i.e.*, in the railway cutting in Por. 77, Par. North, where outcrops are only 50 yds. apart, it is almost horizontal.

In this Marburg sandstone stage Mr. Reid has found *Tæniopteris spatulata* and *Cladophlebis australis*, fossils diagnostic of the Walloon series, on the road between Por. 191, Parish North, and Por. 328, Parish Walloon.

We thus have, if the sandstones lying against the acid tuff are of the same series as those containing these fossils, almost horizontal Walloon

* Verbal communication.

sandstones lying against the vertical acid tuff stage in a line of junction which is apparently approximately parallel to the junction of the acid tuff stage with the schists.

Of the various explanations which arise to explain these peculiar relationships, two seem most probable :—(1) that there has been a Walloon overlap on to strata already affected by the Great Moreton fault; or (2) that a sister fault to the Great Moreton fault has dropped down the Walloon (Marburg) strata against the acid tuff stage, cutting out the Bellevue conglomerate, the Ipswich coal measures, and the Bundanba sandstone. The latter interpretation is the one followed in the map appended.

Whether such a fault is present, or whether the junction line represents the original shore line of the Walloon lake, it would seem to be impossible to prove on the field evidence, as every available outcrop has been visited without satisfaction being obtained.

This obscuration is unfortunate in our examination of the relationship between the Esk–Ipswich series, for it obscures all but the lowest part of the connection between them.

(E) SAHL'S POCKET.

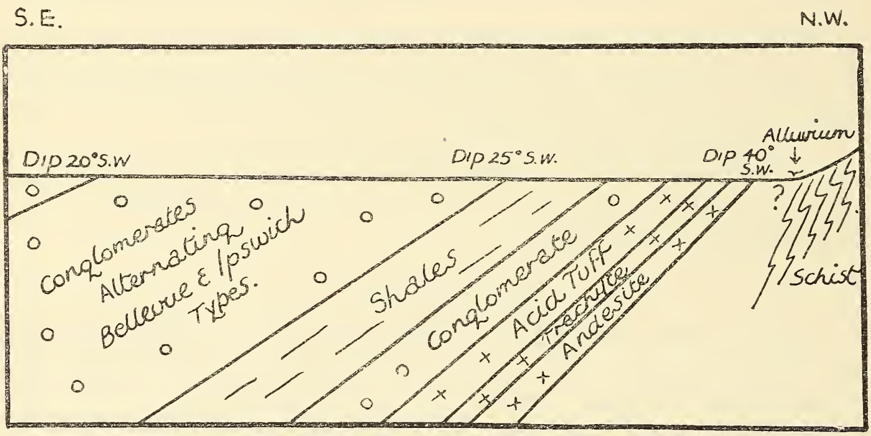
East of Fairney View railway station the Brisbane River makes the most important change in its course, turning from a general S.E. direction to a general E.–W. one, meandering across the junction of the Ipswich basal conglomerate with the schist. Sahl's Pocket is that particular meander enclosing the basal Ipswich just at the turning point.

In the Pocket it was found that the junction of the Mesozoics with the schist was an ordinary unconformity, and not a fault. The schists strike N.N.W. as usual, but the Mesozoics lie on them with the gentle inclination of 20° S.S.E. striking E.N.E.–W.S.W.

A link is established with the Esk series by means of the acid tuff stage which here reappears in Por. 1 with its characteristic trachytes and trachytic tuffs, and andesites, which rocks have a remarkable similarity to those of the Fernvale–Fairney View belt, a vesicular andesite being particularly useful in this equation. The acid tuff stage is separated from the Fernvale series in P.P. 1 by a small thickness of a heavy conglomerate in which the pebbles were of a greenish-grey colour reminiscent of the Bellevue conglomerate in the Northbrook reach.

Succeeding the acid tuff stage in the same portion is an important conglomeratic formation, of a surprising thickness. Like the Bellevue conglomerates and basal Ipswich conglomerate it consists of lenticular beds of grits, sandstones, and shales, interbedded in the pebble beds. But in lithological type it is intermediate between these two; for the pebbles are a mixture of the greenish andesites, cherts, and grits characterising the Bellevue conglomerate, with the rhyolites, trachytes, and jaspers characteristic of the Ipswich basal conglomerate. The interbedded sandstones and shales also vary from the greenish grits, greywackes, and shales of the Esk–Bellevue type, to the brownish and greyish arkosic types characteristic of the basal Ipswich in its type section at College's Crossing. The lowest part of the conglomerate in the extreme westerly outcrop showed the characteristic lithological features of the Bellevue conglomerates of the Northbrook reach ; this character decreased rapidly going up the series, and also geographically to the east.

A beautiful section may be seen on the river bank in Por. 4, where the whole sequence is well exposed from the basal andesite to well up in the conglomerate stage.



TEXT-FIGURE 5.—RIVER SECTION, SAHL'S POCKET.

Here the beds strike N. 30° W. ; and in the south, where the section was begun, they dip at 20° S.W., increasing to 40° at the junction with the schists. There was no evidence to show whether the junction was faulted or not, as a soft soil deposit separated the andesite from the Fernvale series jaspers.

The shale (250 ft.) in the above section is a new development, which is seen again at Mt. Crosby.

(F) PINE MOUNTAIN AREA.

The problems of the geology of the Pine Mountain area are largely that of the faulting which has caused the Pine Mountain inlier. This Pine Mountain mass is composed of the Fernvale series, and is entirely surrounded by the southerly extension of the basal Ipswich formations seen in Sahl's Pocket. The junction between a rhyolite tuff and the schist on the northern boundary of the inlier appears to be a normal unconformable one, as does the eastern boundary, where heavy flat-lying basal Ipswich conglomerates lie against the schist. However, the western and southern boundaries are faults, for the members of the acid tuff stage, and the basal Ipswich conglomerate, are vertical and the junction is a straight line, although the topography of the country is far from flat.

The junction of the basal Ipswich conglomerate with the schist along a line from Por. 494 to Por. 386, Par. Brassall also appears to be faulted, as the Ipswich strata are suddenly uptilted on approaching the boundary.

As the northern and eastern boundaries of the Pine Mountain inlier are unfaulted, and as the junction between the Ipswich and schist in Sahl's Pocket is a normal unconformable one, it appears that there were at the beginning of Mesozoic times troughs between the Pine Mountain inlier and the schist to the north-east. Hence the Pine Mountain faultblock, with its peculiar angular outline, was probably originated in pre-Ipswich times, while posthumous faulting occurred along its western and southern boundaries in post-Ipswich times.

This fault along the western boundary of the inlier may be seen on the map to be continuous with the Great Moreton fault dropping the acid tuff stage against the schist from Fairney View to Northbrook, and it is believed to continue for many miles in a N.N.W. direction.

To the west of Pine Mountain a good vertical section from the acid tuff stage (which is represented by tuff on the northern part and andesite on the southern) to the Aberdare conglomerate at the base of the Bundanba series may be seen ; and one is impressed by the thinness of the Ipswich coal measures representative here relative to its thickness actually in the Ipswich coal measures basin. Hence the extreme thinness of the coal measures series in the Wivenhoe section, and its absence from the Paddy Gully–Esk sections is not surprising.

An important sister fault to the Great Moreton fault runs from N.E. of Wanora in a S.E. direction through Wulkuraka. The nature of this fault, which it is proposed to call the Borallon fault, is believed to be very similar to that of the West Ipswich fault of Cameron, both being faulted anticlines with a strong downthrow to the west, while the West Ipswich fault was the earlier of the two.

It seems that while the Great Moreton fault does not affect the Walloon strata, both the West Ipswich and the Borallon faults do ; and the junction of Walloon and Bundanba strata which in this southern part of the area appear conformable, is apparently a straight line junction[18] due to their attitude induced chiefly by the Borallon fault. This Borallon fault continued northward may be the reason for the junction anomaly of the Fernvale–Fairney View belt.

The present section is to be regarded only as a preliminary account of the Geology of the Pine Mountain area ; for the author intends to complete the field work and to publish the results in a paper entitled "The Structure of the Pine Mountain Area."

(G) College's Crossing–Mt. Crosby–Ipswich Area.

This area serves as the section showing the whole sequence of the sediments of the Ipswich basin as typically developed. Mr. Cameron and Messrs. Reid and Morton have traced the continuity of the basal Ipswich conglomerates from Sahl's Pocket through the Kholo Pocket and along to Mt. Crosby and College's Crossing.

The basal Ipswich conglomerate here has its typical pebble content—more than 80 per cent. of the pebbles are made up of rhyolites and grey-wackes, and other types include trachytes, jaspers, quartzite, aplites, and various metamorphic rocks—andesites and green chert pebbles (the Bellevue type pebbles) are singularly rare. The interbedded sandstones are of two types—brown and grey. The brown types often contain traces of equisetalian fossils ; and are usually flakey. The grey are arkosic in nature, constituents being fresh biotite, quartz, and fresh felspars.

Representatives of the acid tuff stage are seen in this area at various outcrops.

Two good sections are visible at Mt. Crosby, one on the road from Ipswich, and the other on the river bank at the weir.

The road section is the one reported on by Mr. O. A. Jones[19]. Here the conglomerates lie conformably on fossiliferous, fissile green shales carrying an interbedded band of acid tuff similar in thin section to the Brisbane tuff. Lower than these occurs a basic flow of large extent referred to by Cameron and by Jones as a tertiary basalt. This the author regards as a representative of the basal andesite seen from Fernvale southward. A similar section, but lacking the tuff, is seen on the river bank at the weir. Here the " tertiary basalt" has been sectioned, and is shown to be unmistakably related to the basal andesite of Sahl's Pocket.

The series in this sector has an average E.–W. strike, with a dip south from 20°–10°. It is conformably overlain by the thick sediments of the Ipswich coal measure series and the Bundanba sandstone. Between these two occurs the Aberdare conglomerate, a horizon which is persistent in the Ipswich coal basin, but unrepresented elsewhere in South-Eastern Queensland.

Actually within the schist mass to the north of Mount Crosby is a small outlier of fine-grained red shales with *Thinnfeldia odontopteroides,* which represents a small separate basin in the schist.

When traced easterly along the northern margin of the Ipswich coal basin the basal conglomerate thins out, and the percentage of rhyolite pebbles become less. It peters out altogether to the east of College's Crossing, and the shales of the Ipswich coal measure series lie directly on the schist.

A new but transient conglomerate horizon reappears, however, at Pullen Vale. It contains very few rhyolite pebble and its pebbles represent rock types of the schists at Brookfield, from which it has evidently been derived.

(H) Brisbane Area.

In the Brisbane area the Ipswich coal measure shales (here not carrying payable seams) lie for the most part directly on the schist. However, running through Brisbane, at the base of these shales, is a representative of the acid tuff stage, namely, the Brisbane tuff, which has been described by Mrs. C. E. Briggs[20].

In the Aspley district a series with a typical Esk flora and of typical Esk shale lithology occurs associated with the tuff. Here also, it appears that the Esk facies is older than the Ipswich, which is represented by basal grits in the Nundah quarries.

V.—IGNEOUS ACTIVITY.

The earliest igneous activity in Esk–Ipswich times was that in which the lowest stage of the Esk, the andesitic boulder beds, was formed. These consist of rounded or angular pebbles or boulders of only two lithological types set in a homogeneous matrix. Porphyritic andesites form the greater number of the pebbles, and in the hand specimens all the andesites seem to be distinctly related to one another, the average appearance being of glassy phenocrysts of felspar set in a fine-grained grey matrix. The second type of boulders is of a more coarse-grained felspar porphyry, the phenocrysts of felspar being pink.

The dark grey-green matrix is usually very weathered, and no piece has been got fresh enough to section. However, its general appearance suggests an andesitic tuff, well formed crystals of plagioclase being often distinguishable.

The arrangement of the pebbles in the matrix is interesting. Very rarely do two pebbles touch one another. They seem to be spaced at equal distances apart, small pebbles lying side by side with huge boulders. Some localities show nearly all rounded pebbles ; other nearly all angular ones. The writer has never seen any interbedded andesite flows or tuff beds, but at Deep Creek, where the boulders were nearly all rounded, fine greenish unfossiliferous shales were locally interbedded.

The author has not yet formulated a hypothesis of origin capable of successfully explaining all these facts.

These beds are formed only in the most northerly section of the basin examined, and do not occur south of Northbrook. They are overlain, apparently conformably, by the next stage of the Esk, also igneous, the acid tuff stage. This has representatives all over the basin examined, and south of Northbrook forms the lowest stage of sedimentation.

In the type Paddy Gully section, there are three trachyte flows and one andesite, each accompanied by tuffs, the sequence being from earliest to latest, andesitic boulder beds, trachyte, andesites, sediments, trachyte, sediments, trachyte.

The trachytes are all very similar to one another in the hand specimens, consisting of phenocrysts of sanidine and/or an opaque felspar in a fine-grained limonitic groundmass. The associated tuffs are very fine in grain, compact, hard, and yellowish and sometimes silicified. At times, however, they become quite gritty, or pebbly, or even conglomeratic, evidence of deposition under water. Exposure has caused them to weather into rectangular fragments, which form the tops of long ridges and carry a characteristic vegetation.

In the southern part of the area, the acid tuff stage has rhyolitic representatives, *e.g.*, around Pine Mountain, at Mount Crosby, and the Brisbane tuff.

Whether the andesites of the basin south of Northbrook which occur, except at Fairney View, below all the acid extrusives, represent the andesitic boulder stage or the andesite of the acid tuff stage, has not been ascertained, but all three developments are obviously very closely related. Thin sections of the andesite from Mount Crosby weir and Sahl's Pocket show phenocrysts of plagioclase and hornblende in a fine-grained andesitic groundmass in which abundant calcite is to be found. The ferro-magnesian minerals are weathered to chlorite. The richness in calcite is characteristic of the andesites of this stage. The andesites from Fairney View, Fernvale, Wivenhoe, and Northbrook are indistinguishable in the hand specimen from those of Sahl's Pocket and Mount Crosby weir.

The next stage of the Esk, the Esk shales (= basal Ipswich conglomerate) is free from igneous activity. But more than 50 per cent. of the boulders of the conglomerate are of igneous rocks, mainly rhyolites and andesites. Their derivation is as yet uncertain.

The Ipswich coal measure series and the Bundanba series are also free from contemporaneous igneous rocks. In the Esk area, however, there are two acid igneous masses of interest. One of these, Glen Rock, is a fine-grained rhyolite described by Dr. Richards[21], and is definitely intrusive into the Esk shales, which are indurated about its margin, strike in conformity with its outline, and dip steeply away from it.

The other mass, known as the "Esk trachyte," has given rise to controversy[22]. The author believes it to be a laccolitic mass intruded between the Esk shales and the Bundanba sandstones in post-Bundanba (probably Tertiary) times, on the following evidence :—

(1) The Esk shales which surround the mass have an indurated appearance, and dip generally with no constancy of attitude, towards the igneous mass.

(2) The mass itself is intermediate in texture, with short, broad phenocrysts of felspar, and a few odd badly shaped phenocrysts of hornblende set in a fine-grained melanocratic matrix. The name hornblende porphyrite would describe the material in thin section better than the name "trachyte."

(3) It is capped by a small patch of sandstones and sandy shales lithologically similar and with similar dip to the Bundanba sandstones overlying the Esk shales further west. These sediments do not appear indurated.

(4) The weathering shells of the igneous rock give an appearance of conformable bedding with the bedding of the sandy shales and sandstone bands.

(5) Rocks exactly similar in thin section occur in a similar stratigraphical position in Paddy Gully. Here they are surely intrusive, for a sill of coarse gabbro lies between the porphyrite sill (?) and the Bundanba sandstone.

On the Sim Jue Creek road in the Northbrook area there occurs a granite which the author believes intrusive into the Triassic sediments there. The geology of the Northbrook area is, however, to be described in a separate paper in conjunction with Mr. A. K. Denmead, M.Sc.

VI.—THE EVOLUTION OF THE BASIN.

In other parts of the world, particularly in England, emphasis has lately been placed on two important principles. First, that in any basin, more especially a shallow one, lithological phases need not necessarily be constant, but may be transient, migratory, or laterally varying. And second, that conglomerates take on certain characteristic features according to their mode of origin. The application of these two principles to the present problem has given very interesting results, which are discussed hereunder.

Extent and Shorelines.

That part of the Moreton basin discussed in this paper consists geographically of two parts, due to the shape of the D'Aguilar schist block ; one, a northern section developed to the west of the block between Esk and Fairney View, and the second, a southern section developed to the south of the block between Fairney View and Brisbane.

Mr. Cameron[23], when he first studied the Ipswich coal field, thought its northern boundary represented a fault junction with the schist, because of its very straight, angular nature. More detailed work, however, led him to retract this decision[24] and to adopt the view that the northern boundary represented the original shore line of the basin. For the Mesozoic sediments had only very slight dips at this junction, there were no cataclastic effects of faulting visible, and there were no outliers of basin sediments on the D'Aguilar block.

With this latter interpretation the author agrees ; but there still remains the necessity to explain the somewhat unusual angular junction. Dr. Bryan suggests[25] that these angular schist shore cliffs may represent a pre-Mesozoic fault scarp. Scarps are transient things, and unless protected by quick covering by sediments their nature is soon lost by erosion levelling. In the present instance, early Mesozoic sedimentation may have preserved the scarp ; consequently the fault must have occurred

—if at all—very soon before this sedimentation, and its age may be placed as post–Permo-Carboniferous. As yet no evidence of post-Triassic or rejuvenation faulting has been found along this boundary.

As to whether the junction of the Mesozoics with the western edge of the D'Aguilar block is a shore line or not, evidence is not so definite. For here a very strong post-Mesozoic fault has occurred dropping down the Mesozoics relative to the block. No outliers of Esk sediments occur on the block, however ; but this is not to say that they were never deposited there. Should the Great Moreton fault prove to be a rejuvenation of a pre-Mesozoic fault complementary to that of the southern boundary of the D'Aguilar block, then most probably the western boundary was also a shore line.

Depositional Migration in the Basin.

The andesitic boulder beds of the Esk series probably form a continuous[26] belt of constant lithology stretching for a distance of nearly 90 miles from Kinbombi to just north of Bellevue, where they still seem to be well developed. Their absence from all favourable sections south of Bellevue, then, is very remarkable. It cannot be explained as due to suppression by the Great Moreton fault, for in the unconformable junction of the Mesozoics with the schist at Sahl's Pocket they are still lacking.

It is possibly represented by the andesite at the base of all sections from Wivenhoe to Mount Crosby. Also, while the acid tuff stage does not entirely disappear with the andesitic boulder beds, it has only a very thin representative south of Bellevue ; no sediments except thin bands of fine green cherty shales are associated with it.

Thus during the deposition of the andesitic boulder beds and the acid tuff stage, heavy sedimentation was confined to that part of the basin ending at about Northbrook, while the basin south of Bellevue was an area of very slight or no sedimentation. Each of these three changes independently suggests that land conditions were dominant in the southern portion. That is, the basin south of Bellevue was not inundated until the andesitic boulder beds and Esk acid tuff stage had been deposited to the north of Bellevue.

Period of Deposition of the Esk Shales, Bellevue Conglomerates, and Basal Ipswich Conglomerates.

After the deposition of the acid tuff stage, conditions in the basin changed. In the Esk area fine shales were developed which have been traced in the field by Reid and Morton[27] and seen to pass laterally to the south into the Bellevue conglomerates (one of the three heavy conglomeratic deposits of this new phase of deposition). These Bellevue conglomerates have an undetermined thickness, but one much greater than 100 ft. which is the maximum thickness for shore-line deposits as determined by Barrell. According to Barrell's work, therefore, they must be either estuarine or fluviatile in origin. The former origin seems more satisfactory here.

Many different types of very rounded pebbles are represented ; and it may be possible to discover whence the rivers flowed by a detailed study of the pebbles ; *e.g.*, one method would be to plot the progressive percentage of the various types in the different localities, to see whether the progression was also geographical.

What was deposited above the acid tuff stage in the Fernvale–Fairney View area is unknown, because of the position of the Marburg sandstone stage.

In Sahl's Pocket, however, an (estuarine ?) conglomerate even more notable than the Bellevue conglomerate is formed between the acid tuff stage and the Ipswich coal measures. This is continuous with the similar conglomerate at Mount Crosby which thins out towards College's Crossing, and disappears altogether about a mile to the east of the crossing. This conglomerate may represent a composite fan from more than one river flowing into the Ipswich basin in Esk shale times from the D'Aguilar block ; or it may be the simple fan of one very large river (perhaps the westerly migrating ancestor of the Brisbane River).

The basal conglomerates as developed at Kholo, Mount Crosby, and College's Crossing definitely pass under the Waterworks seam, the basal seam of the Ipswich coal field. Therefore, the sediments of the Ipswich coal basin cannot be the lateral equivalents of these conglomerates, but must represent sediments deposited on top of them. This change in deposition is probably to be explained by the gradually lessening gradient causing the currents to slacken and to be thus incapable of carrying coarse sediments. Instead they spread fine sandstones and shales and drift-formed coal seams far out over the basin.

But while none of the fine sediments of the Ipswich coal basin near the northern boundary of the field could be explained as lateral equivalents of the conglomerates, those sandstones and shales between the tuff and the Bundanba sandstone in the South-east Moreton basin contain the lateral equivalents of these estuarine fans, as well as the lateral equivalents of the Ipswich coal measures.

In the area occupied by the Ipswich coal basin and its extension northward as far as Fairney View some sudden alteration in conditions resulted in the formation of the transient Aberdare conglomerate. This was immediately succeeded by the strongly transgressive and immensely thick Bundanba sandstone, which has been traced from the Beaudesert region to Esk.

VII.—EARTH MOVEMENTS.

The earliest earth movement affecting the history of the basin would be the one causing its inception. Deposition seems to have begun first in the Esk–Bellevue part of the basin, so that it may be concluded that downwarp or downthrow affected this area first, and that movement causing the depression of the Ipswich coal basin occurred later. This later movement seems to have been accentuated, if not actuated, by the strong fault forming the southern scarp of the D'Aguilar block; but whether the inception of the Esk-Bellevue part of the basin was accentuated or actuated by faulting along the present western scarp of the D'Aguilar block remains to be proved.

After the deposition of the acid tuff stage the effect of the strong difference in level of the D'Aguilar block had resulted in the inception of a river or rivers forming the Bellevue and basal Ipswich conglomerate. The one feeding the basal Ipswich conglomerate seems to have become the more important by the time the gradient had been lowered sufficiently for the formation of fine deposits instead of coarse ones, for the Ipswich coal measure series spread west round the edge of the basin over the southern part of the Bellevue conglomerate; and east to Brisbane. Some slight alteration in conditions then resulted in forming the Aberdare conglomerate over a somewhat more restricted area than the Ipswich coal measure shales.

A sudden downwarp now caused the widespread transgressive horizon, the Bundanba sandstone. Then (if we accept a Walloon overlap), faulting occurred in the northern part of the area, and the acid tuff stage, basal Ipswich or Bellevue conglomerate, Ipswich coal measures, and Bundanba sandstones, were dropped down against the D'Aguilar block by the Great Moreton fault. Deposition of the Marburg sandstone stage then occurred, followed after a "slight uplift and a period of non-sedimentation and erosion"[28] by the Rosewood stage of the Walloon series. (If, however, we accept the view that a continuation of the Borallon fault caused the present relations between the Marburg stage and the acid tuff stage, then the Great Moreton and Borallon faults did not occur till after the deposition of the Marburg stage.)

Faulting along the West Ipswich and Borallon lines of disturbance then followed with the formation of the many N.W.–S.E. minor faults cutting the coal measures in the mining districts.

It will be seen that although all these major north-west faults appear to belong to the one fault system, it is believed that they were not contemporaneous, but that the order was:—Great Moreton fault, West Ipswich fault, and Borallon fault.

A phase of rapid erosion ensued which was noteworthy in that the erosion was confined to the unstable area to the south and south-east of the angle of the D'Aguilar block with the formation of an early Tertiary or Cretaceous peneplain. Downwarp and renewed sedimentation in this area then occurred, with the deposition of the Tertiary basalts. Then another period of erosion followed, until to-day the (?) Early Tertiary peneplain is again visible.

That adjustment in this area of instability was not complete in Tertiary times is shown by the folding of Tertiary sediments about the old N.W.–S.E. axes.

The above interpretation of the area is indeed very far removed from current opinions. But it seems to be necessary to explain the new facts discovered during the author's work in the field. Though much has been done, much remains to be done, so that the final interpretation of the structure of the area may differ considerably from the one at present placed on it.

VIII.—PALÆOBOTANY.

Palæobotanical data are presented in the form of the accompanying table :—

SPECIES.	LOCALITY.
Elatocladus plana (Feist.)	? 1, *13*, *17*, 31.
Gymnospermous seed	1, 11.
Phœnicopsis elongatus (Morris)	11, *12*, 31.
Bennettites (*Williamsonia*) *sp.*	1.
Otozamites queenslandi Walk.	*13*, 31.
? Otozamites sp.	*15*, *39*.
Nilssonia mortoni Walk.	*10*, 13.
Nilssonia reidi Walk.	11, ? 19.
Nilssonia eskensis Walk.	18, *31*.
Nilssonia sp.	*31*.
? Nilssonia superba Walk.	11.
(*?*) *Nilssonia sp.*	*9*, *31*.
Pterophyllum multilineatum Shir.	1, 22, 23.
Pterophyllum contiguum Schenk	33.
? Pterophyllum nathorsti (Sew).	13, *20*, 33.
Pterophyllum abnorme Eth.	29, 31.
Pterophyllum nathani Walk.	11.
Pterophyllum sp.	*10*, *17*.
Pseudoctenis eathiensis (Rich.)	11, *12*, 16, 19, *31*, 33, 34, 40.
Podozamites ? lanceolatus (L. & H.)	11.
Ginkgo antarctica Saporta	1.
Ginkgo digitata Brongn.	1, *12*, 19, 22, 24, *31*.
Ginkgo cf. magnifolia Font.	*12*, 14, 22, 31.
Ginkgo ? sibirica Heer	9, 19.
Ginkgo sp.	11.
Ginkgo sp.	*11*.
Baiera simmondsi (Shir.)	1, 19, 34.
Baiera bidens (T. Woods)	1, 11, *13*, 19, 22.
Baiera ginkgoides Shir.	1.
Baiera ipsviciensis Shir.	1.
Baiera tenuifolia John.	*1*.
Baiera sp.	*31*.
Baiera sp.	*13*.
Stachyopitys annularoides Shir.	1, 26.
Stachyopitys simmondsi Shir.	1.
Dictyophyllum rugosum L. &. H	1, 11.
Dictyophyllum davidi Walk.	33.
Hausmannia buchii Andrae	35.
Coniopteris delicatula Shirley	28.

Species.	Locality.
Cadopohlebis australis (Morris)	1, 3, 4, *10*, *11*, *12*, *13*, 14, 16, 22, 23, 27, *31*, 32, 33.
Cladophlebis lobifolia (Phill.)	*10*, 11, *13*, 19, 35.
Cladophlebis sp.	*10*.
Cladophlebis sp.	*10*.
Cladophlebis johnstoni Walk.	*10*, *31*.
Cladophlebis roylei Arber	1, 22, 29.
Todites williamsoni (Brongn.)	*10*, 13.
Thinnfeldia feistmanteli John.	1, 3, 5, 6, 7, *9*, *10*, 11, *13*, *17*, 23, 26, 37, 38
Thinnfeldia odontopteroides (Morr.)	1, 7, *10*, *11*, *12*, *13*, *15*, *17*, 23, *24*, 30, *31*.
Thinnfeldia lancifolia (Morr.)	1, 9, *10*, 11, *12*, *15*, *17*, 19, 23, *31*, 33, 38, 40.
Thinnfeldia acuta Walk.	*12*, 23.
Thinnfeldia talbragarensis Walk.	8, *10*, 11, *12*, *15*.
Thinnfeldia eskensis Walk	13 *31*, 35.
Thinnfeldia sp.	*9*.
Danæopsis hughesi Feist.	1, 13.
Asterotheca denmeadi Walk.	*10*, 13.
Asterotheca hillæ Walk.	*9*, 11, *12*.
Neuropteridium moombraense Walk.	13, *31*.
Stenopteris elongata (Carr.)	1, 7, 23, *24*, 30.
Tæniopteris tenison-woodsi Eth.	1, *9*, 11, *12*, 14, 16, *17*, 22, 24, 26, 36.
Tæniopteris carruthersi Ten.-Woods	26, 30, 32.
Tæniopteris lentriculiforme Eth.	1.
Tæniopteris dunstani Walk.	1, 25.
Tæniopteris ? wainamattæ Feist.	21.
Tæniopteris crassinervis Feist.	11, *15*, 18, 19, 27.
Anthrophyopsis grandis Walk.	10.
Sphenopteris superba Shir.	1, 9, 11, *12*.
Sphenopteris lacunosa Shir.	1.
Sphenopteris eskensis Walk.	36.
Sphenopteris ? pecten Halle	19.
Sphenopteris sp.	*9*.
Schizoneura cf. Africana (Feist.)	4, 10.
Schizoneura sp. α Sew.	10, 11, *15*, 17.
Schizoneura sp.	2.
Neocalamites cf. carrerei Zeill.	1, 3.
Neocalamites hœrensis Schimp.	1, 32.
Phyllotheca australis Brongn.	1.
Equisetites rotiferum T. Woods	7.
Chiropteris sp.	*9*.

Italicised numerals signify occurrences not noted in previous publications.
Ordinary numerals signify occurrences noted in previous publications.

LOCALITY KEY.

1. Denmark Hill.
2. 4-ft. coal seam.
3. Bundanba.
4. Ebbw Vale Colliery.
5. Dinmore.
6. Bremer Basin Colliery.
7. Tivoli.
8. Por. 366, Par. Brassall.
9. Por. 36, Par. Wivenhoe.
10. Por. 74, Par. Wivenhoe.
11. Por. 42, Par. Wivenhoe.
12. Por. 52, Par. Burnett.
13. Road between Pors. 70 and 76, Par. Wivenhoe.
14. ¼ mile west of Esk P.O.
15. Por. 94, Par. Esk.
16. Por. 33, Par. Esk.
17. Por. 81, Par. Esk.
18. Por. 85, Par. Esk.
19. Por. 24, Par. Esk.
20. Por. 32, Par. Esk.
21. Ipswich.
22. Yeronga.
23. Petrie's Quarry, Albion.
24. Campbell's Quarry, Albion.
25. Windsor Town Quarry.
26. Nundah.
27. Toombul.
28. Shorncliff, Sandgate.
29. Redbank, near Mt. Esk.
30. Mt. Esk.
31. Road between Pors. 155 and 157, Par. Biarra.
32. Por. 32, Par. Northbrook.
33. Por. 28v, Par. Biarra.
34. Coal Creek, near Esk.
35. 6 miles north of Esk.
36. Railway cutting, Ottaba.
37. Mt. Brisbane R.O., 5 miles north of Esk.
38. Kilcoy Range, above Cressbrook.
39. Por. 92, Par. Esk.
40. Colinton.

Localities 1–20 are arranged in descending stratigraphical succession.
Localities 21–29 represent unplaced horizons in the Ipswich–Brisbane area.
Localities 30–40 represent unplaced horizons in the Esk area.

Very little use has been made of palæontology during the work for three chief reasons :—

(1) The flora collected represents only a very small percentage of the forms present on any horizon. The only horizon which is collected from with any degree of completeness is Denmark Hill.

(2) The unsatisfactory state of the palæobotany of the world for detailed correlatory purposes.

(3) Faulty deposition of the plant remains ; by which is meant that the plant fragments carried away and deposited within the basin by no means represent all the forms living even in the district which was the immediate source of the deposit.

It will be seen that the stratigraphy will of necessity be used to solve palæobotanical problems and not *vice versa,* in future work.

Much palæobotanical descriptive work remains to be done. The Esk shales are marvellously rich in fossils, which are well preserved in a colour which contrasts with the matrix. In Sheep Station Creek the tissue of the plant is preserved as a carbonaceous film, which could be treated by the latest palæobotanical methods.

IX.—CORRELATION AND AGE.

The following table of correlation for the Ipswich and Esk shales is satisfactory on the evidence so far to hand.

Ipswich Area.	Esk Area.
Bundanba sandstone	Bundanba sandstone
Ipswich coal measures	Period of no deposition
Basal Ipswich conglomerate = Bellevue conglomerate	= Esk shales
Acid tuff and andesite*	= Acid tuff stage Andesitic boulder beds.

This table shows how closely related the Ipswich coal measures and Esk shales really are. Florally (at the present stage of the palæobotany of the world) they may be regarded as one, and the whole flora compared with that of the rest of Gondwana Land.

The very close resemblance of the flora to that of the Molteno beds of the Karroo system of South Africa had led all palæontologists to place the two as of approximately the same age. Recent work by du Toit[29] in South Africa has suggested that the Molteno flora is essentially Upper Triassic (Keuper) in age, and not Rhætic as formerly supposed. The Ipswich–Esk flora is therefore automatically to be regarded as of the same age, *i.e.*, Keuper.

X.—CONCLUSION AND ACKNOWLEDGMENT.

In conclusion, it is to be stated that the working out of this complex area is by no means finished, although it is believed that the problem of the relationship of the Esk shales to the Ipswich coal measures has been correctly solved.

Very sincere thanks are given to Drs. Richards, Bryan, and Whitehouse, who directed the author's interests into this fascinating study of ever-changing conditions, and who were always ready to discuss the various problems as they arose. No one realises more than the author the extent of the inspiration gained from them. Mr. C. C. Morton gave many valuable field data ; and Misses Buchanan, Ferguson, Holdsworth, and Hooper made sections of some of the igneous rocks.

* These andesites may represent the andesitic boulder beds.

APPENDIX A.

BIBLIOGRAPHY OF THE IPSWICH COAL MEASURES.

In this bibliography, which is complete to the best of the author's knowledge, the following abbreviations are used :—

A.A.A.S. ..	Australian Association for the Advancement of Science.
A.R.D.M. N.S.W.	Annual Report of the Department of Mines, New South Wales.
A.R.D.M.Q. ..	Annual Report of the Department of Mines, Queensland.
A.R.G.S.Q. ..	Annual Report of the Geological Survey of Queensland.
G.S.Q.P. ..	Geological Survey of Queensland Publication.
P.L.S. N.S.W. ..	Proceeding of the Linnean Society of New South Wales.
Proc. N.Z. Inst. ..	Proceedings of the New Zealand Institute.
P.R.S. N.S.W. ..	Proceedings of the Royal Society of New South Wales.
P.R.S.Q. ..	Proceedings of the Royal Society of Queensland.
Q. Geogr. Jnr. ..	Queensland Geographical Journal.
Q.G.M.J. ..	Queensland Government Mining Journal.
Q.J.G.S. ..	Quarterly Journal of the Geological Society of London.

1845. Strzlecki .. Physical Descriptions of New South Wales and Van Diemen's Land.

1847. McCoy .. On the Fossil Botany of Rocks associated with Australian Coals. Ann. Mag. Nat. Hist., vol. xx. (1st series), p. 148.

1872. R. Daintree .. The Geology of Queensland, Q.J.G.S., vol. 28, p. 271.

1872. W. Carruthers Fossil Plants of Queensland, Q.J.G.S., vol. 28, p. 350.

1875. A. C. Gregory Report on the Geology of Parts of Wide Bay. Qld. Parl. Papers, Votes and Proceedings.

1876. A. C. Gregory Report on Coal Deposits of West Moreton and Darling Downs district. Qld. Parl. Papers, Votes and Proceedings, vol. 111, p. 387.

1878. J. Hector .. Relative Ages of Australian, Tasmanian, and New Zealand Coal Measures. Proc. N.Z. Inst., vol. x., p. 352.

1879. A. C. Gregory .. Geological Features of the South-Eastern District of the Colony of Queensland. Qld. Parl. Papers, Votes and Proceedings, vol. 11, p. 369.

1880. O. Feistmantel Notes on the Fossil Flora of Eastern Australia and Tasmania. P.R.S. N.S.W., vol. xiv., p. 103.

1882. J. E. Tenison-Wood Various Deposits of Fossil Plants in Queensland. P.L.S. N.S.W., vol. vii., p. 95.

1883. J. E. Tenison-Wood Fossil Flora of the Coal Deposits of Australia. P.L.S. N.S.W., vol. viii., p. 37.

1883. J. E. Tenison-Wood Coal Resources of Queensland (to be found in vol. iii., p. 249, of Rands' Collection of Reprints, the University of Queensland Geological Library.

1886. R. L. Jack .. Handbook of Queensland Geology, G.S.Q.P. 31.

1887. W. H. Rands .. Geological Map of Brisbane and its Environs, G.S.Q.P. 34.

1887. W. H. Rands .. Geology of Beenleigh, Logan and Albert Rivers, G.S.Q.P. 36.

1888. R. L. Jack .. On Some Salient Points in the Geology of Queensland. A.A.A.S. Sydney.

1889. W. H. Rands .. Albert and Logan Districts, G.S.Q.P. 51.

1890. W. H. Rands .. Brookfield, Pullen Vale, and Moggill, G.S.Q.P. 63.

1891. R. L. Jack .. Land Slips at Marburg, G.S.Q.P. 77, p. 1.
1891. W. H. Rands .. Coal in the Parish of Noosa, G.S.Q.P. 64.
1891. T. W. E. David The Clarence Basin, A.R.D.M. N.S.W., p. 223.
1892. R. L. Jack and R. Etheridge Geology and Palæontology of Queensland and New Guinea, G.S.Q.P. 93, p. 320, &c.
1894. W. H. Rands .. Pine Mountain District, A.R.G.S.Q. for 1894. G.S.Q.P., 103, p. 26.
1895. R. L. Jack .. Coal near Brisbane, G.S.Q.P. 108.
1897. J. Shirley .. *Baiera bidens*, P.R.S.Q., vol. xii., p. 74.
1897. J. Shirley .. *Pterophyllum multilineatum*, P.R.S.Q., vol. xii., p. 89.
1897. R. L. Jack .. Coal near Brisbane, G.S.Q.P. 143.
1898. J. Shirley .. Additions to Fossil Flora of Queensland, G.S.Q.P. 128, Bull. 7.
1898. W. S. Dun .. Notes on Australian Tæniopterids, A.A.A.S., vol. vii., p. 384.
1899. W. E. Cameron The Northern Boundary of the Ipswich Coal Field G.S.Q.P. 143, p. 13.
1899. W. E. Cameron The Trias-Jura of West Moreton, G.S.Q.P 14.
1902. J. Shirley .. Notes on Duaringa, Ipswich, and Dawson River. G.S.Q.P. 171, Bull. 18.
1903. H. I. Jensen .. The Geology of the Glass House Mountains District, P.L.S. N.S.W., vol. 28, p. 842.
1904. W. Fryar .. Sinking for Coal in the Logan District, Q.G.M.J. June, p. 296.
1904. L. C. Ball .. Iron Ore Deposits in the Ipswich Coal Measures, G.S.Q.P. 194, p. 56.
1905. W. E. Cameron Geology of the West Moreton and Ipswich Coal Field, Q.G.M.J., p. 459, and (1906) G.S.Q.P. 204.
1906. H. I. Jensen .. Geology of the Volcanic Area of East Moreton and Wide Bay, P.L.S. N.S.W., vol. 31, pt. 1, p. 88.
1907. W. E. Cameron Coal and Gravel at Nundah, Q.G.M.J., p. 11.
1907. L. C. Ball .. The Occurrence of Coal in the Vicinity of Brisbane, Q.G.M.J., p. 580.
1907. E. O. Marks .. The Trias-Jura of S.E. Moreton, Q., G.S.Q.P. 225.
1908. W. E. Cameron The Bundanba Sandstone at Toorbul Point, A.R.D.M.Q., p. 172.
1909. H. I. Jensen .. Notes on the Geology of the Mount Flinders and Fassifern Districts, Qld., P.L.S. N.S.W., vol. 34, pt. 1, p. 67.
1910. E. O. Marks .. Coal, Gravel, and Water, E. Moreton, Q.G.M.J., p. 285.
1911. Wearne and Woolnough Geology of West Moreton, Qld., P.R.S. N.S.W., vol. xlv., p. 137.
1911. W. E. Cameron Coal at Ipswich and Dalby, G.S.Q.P. 235, p. 1.
1912. E. O. Marks .. Geological Age of Volcanic Activity in S.E. Qld., P.R.S.Q., vol. xxiii., pt. 2, p. 141.
1912. W. E. Cameron Coal at Eden Park, near Goodna, Q.G.M.J., p. 321.
1913. B. Dunstan .. East Moreton Coal Measures, Q.G.M.J., p. 353.
1913. W. E. Cameron The Ipswich Coal Field, Q.G.M.J. p. 412.
1913. B. Dunstan .. Coal Resources of Queensland, G.S.Q.P., 239.
1914. L. C. Ball .. Prior's Coal Pit, Moggill, Q.G.M.J., p. 412.
1914. W. E. Cameron City Colliery in Ipswich, Q.G.M.J., p. 518.
1915. A. B. Walkom Mesozoic Floras of Queensland, pt. 1 (*a*), (*b*), G.S.Q.P. 252.
1916. L. C. Ball .. Coal near Belmont, Q.G.M.J., p. 16.

1916. H. C. Richards — Volcanic Rocks of S. E. Qld., P.R.S.Q., vol. 27, No. 7.
1916. R. J. Tillyard — Mesozoic and Tertiary Insects, G.S.Q.P. 253.
1916. B. Dunstan .. Harrap's Geography of Queensland, p. 166.
1916. L. C. Ball .. Note on a great Fault System on the East Moreton District, Q.G.M.J., p. 169.
1916. W. E. Cameron — The Ipswich Coal Field, Q.G.M.J., p. 370.
1917. A. B. Walkom — Mesozoic Flora of Queensland, pt. 1 (*c*), G.S.Q.P. 257.
1917. A. B. Walkom .. Mesozoic Flora of Queensland, pt. I. (*d*), (*e*), (*f*), G.S.Q.P. 259.
1918. A. B. Walkom .. Geology of the Lower Mesozoic of Queensland, P.L.S. N.S.W., vol. 43, p. 37.
1918. A. B. Walkom .. Mesozoic Floras of Queensland, pt. II., G.S.Q.P. 262.
1919. B. Dunstan .. Sandgate-Zillmere Geology, Q.G.M.J., p. 53.
1919. A. B. Walkom .. Mesozoic Floras of Queensland, pts. III. and IV., G.S.Q.P. 263.
1920. B. Sahni .. Petrified Plants from Queensland, Mesozoic and Tertiary, G.S.Q.P. 267.
1920–22. B. Dunstan — The Geology of Ipswich, Q. Geogr. Jour., vol. 36–37, p. 36.
1920. W. E. Cameron .. Palmer's Property (Bundanba), Q.G.M.J., p. 102.
1921. J. H. Reid .. Geology of the Walloon–Rosewood Coalfield, Q.G.M.J., p. 310.
1922. C. C. Morton .. Coal Prospects of the Narangba District, Q.G.M.J., p. 190.
1922. J. H. Reid .. Petroleum Prospects in Beaudesert, Q.G.M.J., p. 431.
1922. J. H. Reid .. Geology of the Walloon–Rosewood Coalfield, G.S.Q.P. 272.
1922. J. H. Reid .. Coal Measures of West Moreton District, Q.G.M.J., p. 462.
1922. J. H. Reid and C. C. Morton — Contributions to the Geology of Ipswich, part I., Q.G.M.J., p. 355.
1922. J. H. Reid and C. C. Morton — Contributions to the Geology of Ipswich, pt. II., Q.G.M.J., p. 390.
1922. E. O. Marks .. Contributions to the Geology of Ipswich, Q.G.M.J., p. 478.
1922. W. E. Cameron — Map of the Ipswich Coalfield, G.S.Q.P. 271.
1923. W. E. Cameron — Contributions to the Geology of Ipswich, Q.G.M.J., p. 166.
1923. J. H. Reid and C. C. Morton — Contributions to the Geology of Ipswich, Q.G.M.J., p. 167.
1923. E. O. Marks .. Contributions to the Geology of Ipswich, Q.G.M.J., p. 208.
1923. J. H. Reid and C. C. Morton — Contributions to the Geology of Ipswich, Q.G.M.J., p. 249.
1923. E. O. Marks .. Contributions to the Geology of Ipswich, Q.G.M.J., p. 422.
1923. J. H. Reid and C. C. Morton — Contributions to the Geology of Ipswich, Q.G.M.J., p. 423
1923. C. C. Morton — South Moreton Geology, Q.G.M.J., p. 244.
1923. E. C. Saint-Smith — Notes on Oil at Wolston, Q.G.M.J., p. 56.
1923. J. H. Reid and C. C. Morton — Geology of the Country between Esk and Ipswich, Q.G.M.J., p. 7.
1923. J. H. Reid .. Notes on the Walloon Jurassic Flora, P.R.S.Q., vol. 34, p. 168.
1924. J. H. Reid and C. C. Morton — Contributions to the Geology of Ipswich, Q.G.M.J., p. 282.
1924. A. B. Walkom .. On Fossil Plants from Bellevue, near Esk, Mem. Qld. Mus., vol. 8, pt. I., p. 1.
1925. W. H. Bryan .. Earth Movements in Queensland, Pres. Add. R.S.Q., vol. 37, p. 3.

1926. O. A. Jones .. The Tertiary Deposits of Moreton District, S.E. Qld., P.R.S.Q., vol. 38, No. 2.

1927. W. H. Bryan and F. W. Whitehouse Later Palæogeography of Queensland, P.R.S.Q., vol. 38, p. 103.

1929. Mrs. C. Briggs The Brisbane Tuff, P.R.S.Q., vol. 40, p. 147.

APPENDIX B.

BIBLIOGRAPHY OF MESOZOIC ROCKS IN THE ESK DISTRICT.

1901. L. C. Ball .. Notes on the Taromeo District, A.R.G.S. for 1900, Q.S.Q.P. 159.

1901. C. F. V. Jackson Mines near Esk, Q.G.M.J., pp. 466, 468, 469, 530.

1906. L. C. Ball .. The Upper Brisbane Valley, Q.G.M.J., p. 470.

1912. L. C. Ball .. Mines in the Parish of Taromeo, Q.G.M.J., p. 111.

1912. E. O. Marks .. Prospects of Coal at Esk, Q.G.M.J., p. 322.

1912. E. O. Marks .. On the Geological Age of S. E. Qld., Volcanic Rocks, P.R.S.Q., p. 139.

1915. A. B. Walkom Mesozoic Floras of Queensland, pt. I. (*a*), (*b*), G.S.Q.P. 252.

1916. H. C. Richards Volcanic Rocks of S. E. Queensland, P.R.S.Q., vol. 27, No. 7.

1917. A. B. Walkom .. Mesozoic Floras of Queensland, pt. 1 (*c*), G.S.Q.P. 257.

1917. A. B. Walkom .. Mesozoic Floras of Queensland, pt. I. (*d*), (*e*), (*f*), G.S.Q.P. 259.

1918. A. B. Walkom .. The Geology of the Lower Mesozoic Rocks of Queensland, P.L.S. N.S.W., vol. 43, pt. 1, p. 37.

1923. J. H. Reid .. Note on the Walloon Jurassic Flora, P.R.S.Q., vol. 34, p. 168.

1923. J. H. Reid and C. C. Morton Geology of the Country between Esk and Ipswich, Q.G.M.J., p. 7.

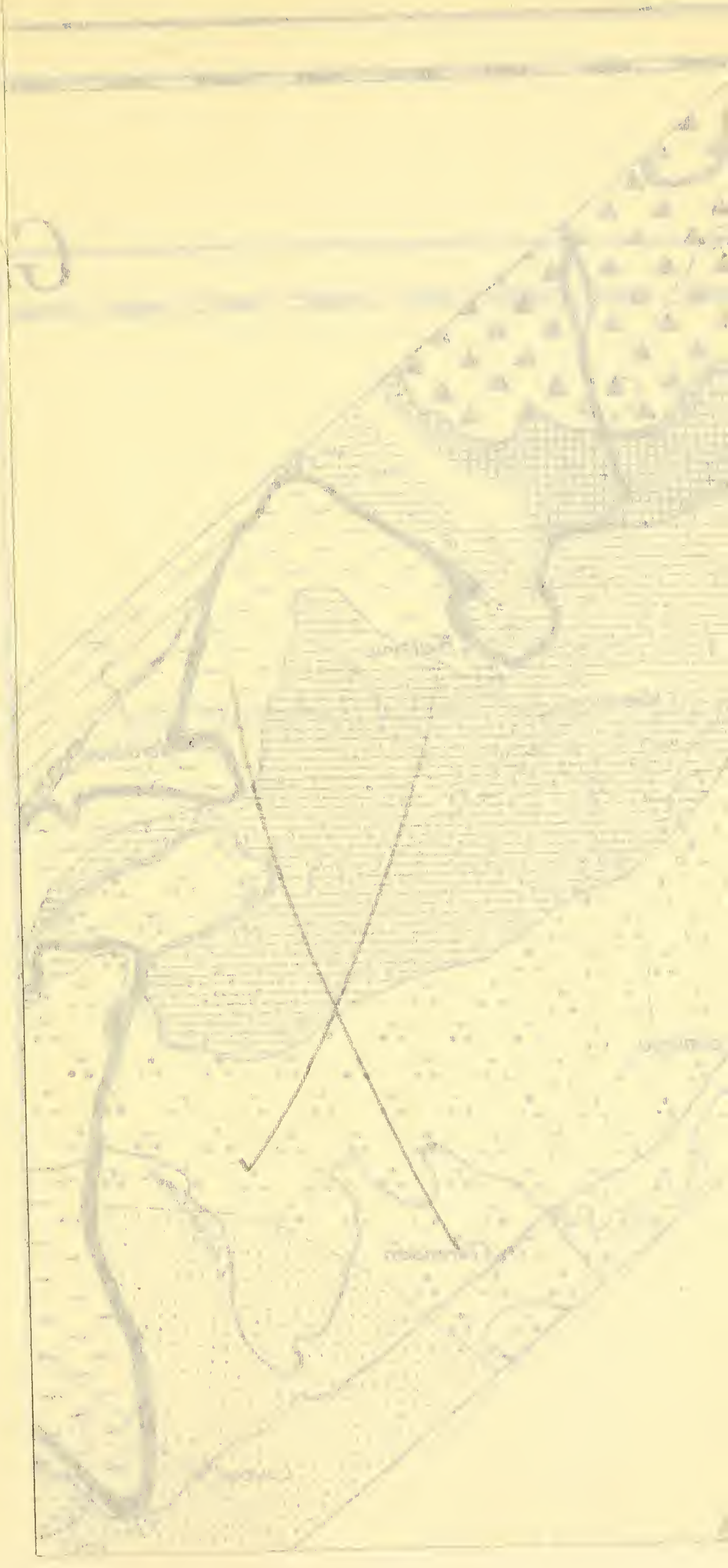
1924. A. B. Walkom On Fossil Plants from Bellevue, near Esk, Mem. Qld. Mus., vol. 8, pt. 1, p. 1.

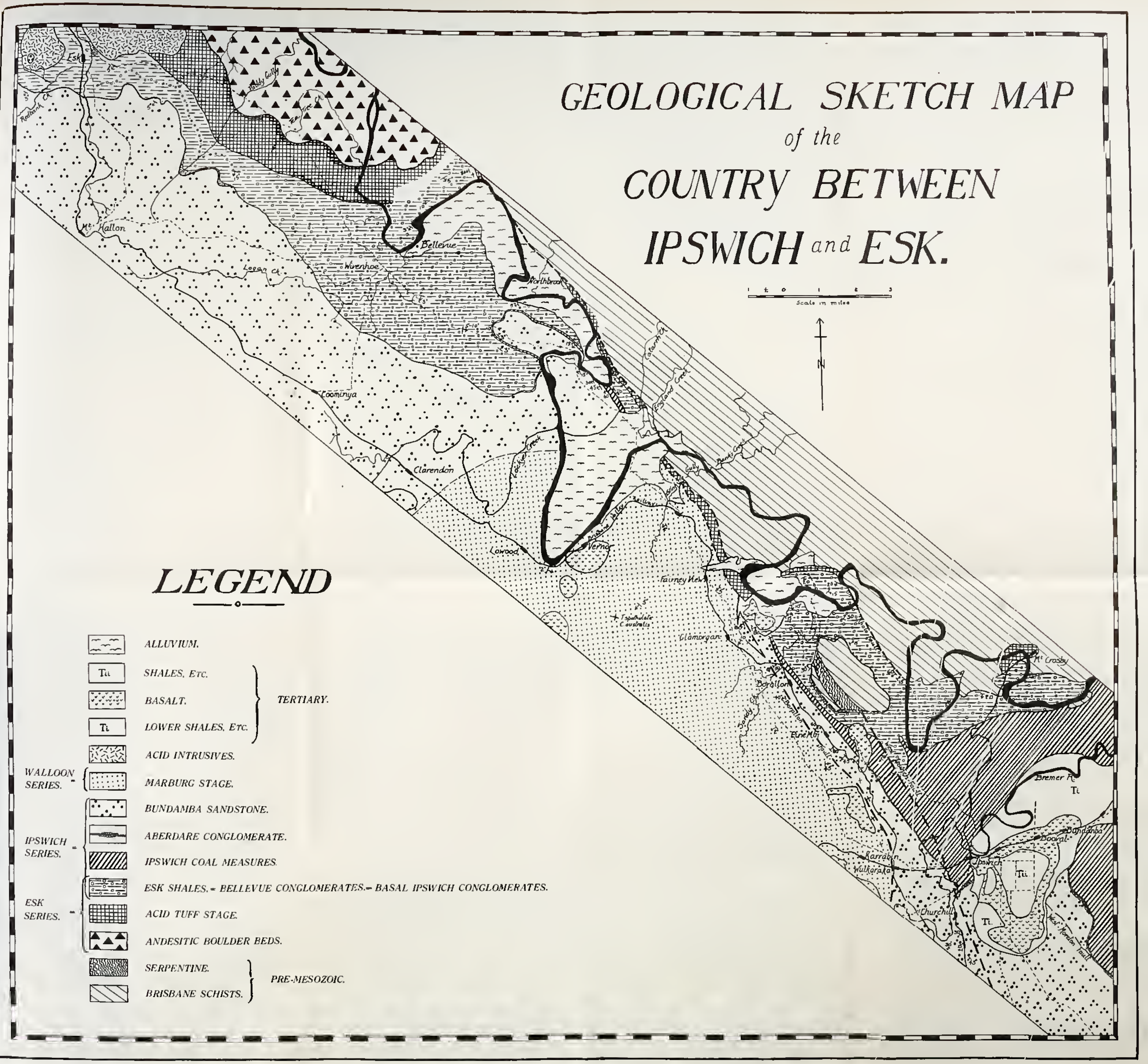
1926. H. C. Richards Volcanic Activity in Queensland, A.A.A.S. (1924), p. 285–287.

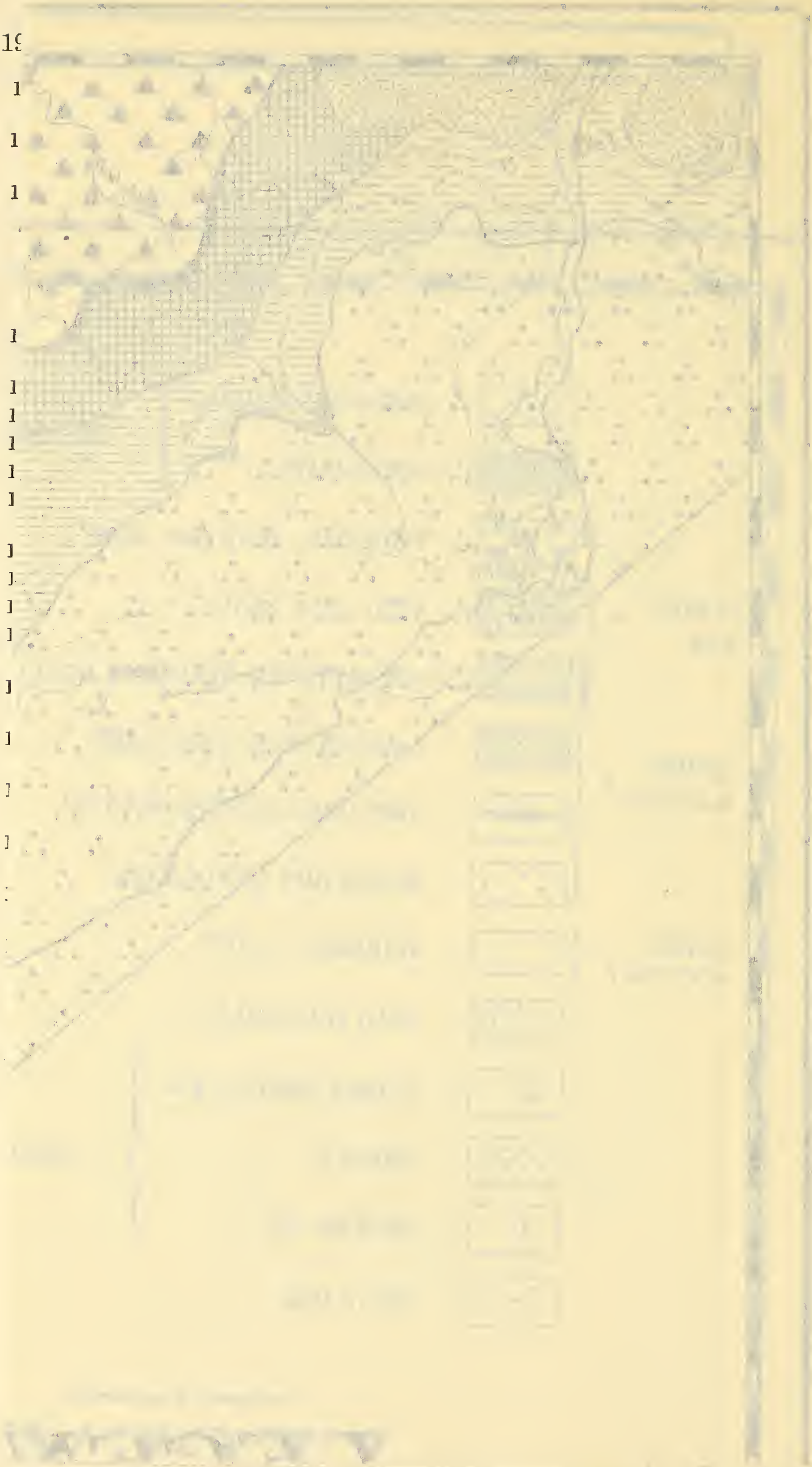
1928. A. B. Walkom .. Fossil Plants from the Esk District, vol. 53, pt. 4, P.L.S. N.S.W.

The Murgon–Goomeri District.

1925. J. H. Reid .. Geology of the Murgon–Goomeri District, Q.G.M.J., p. 87.




GEOLOGICAL SKETCH MAP
of the
COUNTRY BETWEEN
IPSWICH and ESK.
Scale in miles
N
LEGEND
ALLUVIUM.
SHALES, ETC.
BASALT.
LOWER SHALES, ETC.
TERTIARY.
ACID INTRUSIVES.
WALLOON SERIES.
MARBURG STAGE.
BUNDAMBA SANDSTONE.
ABERDARE CONGLOMERATE.
IPSWICH SERIES.
IPSWICH COAL MEASURES.
ESK SHALES. = BELLEVUE CONGLOMERATES. = BASAL IPSWICH CONGLOMERATES.
ESK SERIES.
ACID TUFF STAGE.
ANDESITIC BOULDER BEDS.
SERPENTINE.
BRISBANE SCHISTS.
PRE-MESOZOIC.
Esk
Redbank Ck.
Mt. Hallon
Logan Ck.
Bellevue
Wivenhoe
Northbrook
England Creek
Coominya
Clarendon
Lowood
Vernor
Fairney View
Glamorgan
Borallon
Mt. Crosby
Bremer R.
Bundamba
Dooral
Ipswich
Karrabin
Walkaraka
Churchill
West Moreton Fault



REFERENCES.

1. Australian Encyclopædia, 1925.
2. 1905, Cameron.
3. 1910, Marks.
4. 1899, Cameron.
5. 1912, Marks.
6. 1915, 1917, 1918, 1919, Walkom.
7, 1916, Tillyard.
8. 1921, 1922, Reid and Morton.
9. 1922, 1923, Marks, Cameron, Reid, and Morton.
10. 1924, Reid and Morton.
11. 1923, Reid and Morton.
12. 1916, Richards.
13. 1921, 1923, Reid.
14. Op. cit.
15. 1924, Walkom.
16. 1928, Walkom.
17. 1921, Reid.
18. 1922, Cameron.
19. 1927, Jones.
20. 1929, Briggs.
21. 1916, Richards.
22. 1912, Marks ; 1916, Richards ; 1923, Reid and Morton ; 1926, Richards.
23. 1899, Cameron.
24. 1905, Cameron.
25. Verbal communication.
26. Unpublished work by Mr. E. C. Tommerup.
27. 1923, Reid and Morton.
28. 1922, Reid, p. 12.
29. 1927, du Toit, Annals S. African Museum, vol. XXII., pt. 2. "The Fossil Flora of the Upper Karroo Beds."

The Royal Society of Queensland.

Report of Council for 1928.

To the Members of the Royal Society of Queensland.

Your Council has pleasure in submitting its Report for the year 1928.

Thirteen original papers were read before the Society and published during the year. Three public meetings were held. On 10th July, 1928, Dr. C. M. Yonge, leader of the Great Barrier Reef Expedition, Dr. Stephenson, and Messrs. Tandy and Russell outlined the work contemplated. On 16th July, 1928, Sir Arnold Theiler gave an address on ''Problems of Phosphorus Deficiency of Stock.'' On 4th March, 1929, Professor Johannes Schmidt, D.Sc., Ph.D., Director of the Carlsberg Laboratory, Copenhagen, and leader of the Danish Oceanographical Expedition, delivered a lecture on the life history of the eel.

The Council wishes to acknowledge generous subsidies amounting to £147 from the Queensland Government towards the cost of printing the Proceedings of the Society. Appreciative acknowledgment is also made to the University of Queensland for housing the library and providing accommodation for meetings.

The membership roll consists of 4 corresponding members, 6 life members, and 176 ordinary members. During the year there were five resignations, and nine new members were elected. The deaths of Dr. J. V. Danes, of the Czech University, Prague, a corresponding member, and of Mr. W. R. Colledge, a past president of the Society and a frequent contributor to the proceedings, are reported with regret. Mr. Rowland Illidge, a former honorary librarian of the Society, has been lost from the ranks of Queensland biologists by death.

There were nine meetings of the Council. The attendance was as follows:—E. W. Bick 8, W. H. Bryan 7, J. V. Duhig 3, E. J. Goddard 2, R. W. Hawken 4, D. A. Herbert 9, T. G. H. Jones 4, H. A. Longman 4, E. O. Marks 8, T. Parnell 7, H. C. Richards 6, C. T. White 7, Dr. J. P. Lowson was unable to attend as the hour of the meetings was unsuitable.

T. PARNELL, President.

D. A. HERBERT, Hon. Secretary.

THE ROYAL SOCIETY OF QUEENSLAND.

Cr. STATEMENT OF RECEIPTS AND EXPENDITURE FOR YEAR ENDING 31st DECEMBER, 1928. **Dr.**

Receipts.

	£	s.	d.
Bank Balance, 31st December, 1927	36	0	6
Subscriptions	147	10	6
Government Subsidy on cost of Printing	147	0	0
Sale of Reprints	15	10	0
Sale of Bookcase	10	0	0
Exchanges		7	6
Cheque B976134, not presented at 31st December, 1928	15	0	0
	£371	8	6

Expenditure.

	£	s.	d.
Government Printer—			
Stationery Account	7	7	3
Printing Account, Volume and Abstracts	294	10	0
Hon. Secretary (Postages)	11	0	0
Library Furniture	9	9	3
Library Shelving	15	0	0
State Government Insurance		13	0
Advertising Lectures	5	6	0
Lanternist	1	10	0
Exchanges		8	10
Cheque Book		10	0
Bank Charges		10	0
Balance in Q.N. Bank, 31st December, 1928	25	4	2
	£371	8	6

H. J. PRIESTLEY, Hon. Auditor.

E. W. BICK, Hon. Treasurer.

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Abstract of Proceedings, 25th March, 1928.

The Annual Meeting of the Society was held in the Geology Lecture Theatre of the University at 8 p.m. on Monday, 25th March, 1928. The President, Professor T. Parnell, occupied the chair. Apologies for absence were received from Professors E. J. Goddard and H. C. Richards and from Mr. T. Rimmer. The minutes of the previous meeting were read and confirmed. The annual report and balance sheet were adopted.

The following officers were elected for 1929:—

President: Professor J. P. Lowson, M.A., M.D.

Vice-Presidents: Professor T. Parnell, M.A. (*ex officio*) and Mr. J. B. Henderson, F.I.C.

Hon. Secretary: Mr. F. A. Perkins, B.Sc. Agr.

Hon. Librarian: Mr W. D. Francis.

Hon. Treasurer: Mr. E. W. Bick.

Hon. Editors: Mr. H. A. Longman, F.L.S., C.M.Z.S., and Dr. W. H. Bryan, M.C.

Hon. Auditor: Professor H. J. Priestley, M.A.

Members of Council: Dr. C. D. Gillies, M.B., B.S., M.Sc., Professor R. W. Hawken, B.A., M.E., M. Inst. C.E., Mr. D. A. Herbert, M.Sc., Dr. T. G. H. Jones, A.A.C.I., Mr. R. Veitch, B.Sc.

Mr. W. G. Wells was nominated for ordinary membership and Mr. C. Schindler for associate membership.

Professor J. P. Lowson was inducted to the position of President for 1929. Professor T. Parnell delivered his Presidental Address entitled "Modern Developments of Physical Science." On the motion of Professor R. W. Hawken, seconded by Mr. J. B. Henderson, a vote of thanks was accorded the retiring president for his address. A paper by Dr. T. G. H. Jones and Mr. F. B. Smith, B.Sc., on "The Volatile Oil of Queensland Sandalwood" was laid on the table. Mr. H. A. Longman expressed the Society's appreciation of the presence of His Excellency the Governor.

Abstract of Proceedings, 29th April, 1929.

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre on Monday, 29th April, 1929, at 8 p.m.

The President, Professor J. P. Lowson, in the chair, and about thirty members present. Apologies for absence were received from Messrs. Francis and Veitch.

The minutes of the previous meeting were read and confirmed. Mr W. G. Wells (ordinary) and Mr. C. Schindler (associate) were unanimously elected members of the Society.

Miss D. Hill, B.Sc., Miss N. Holdsworth, and Mr. L. F. Mandelson, B.Sc., Agr., were nominated for ordinary membership.

Dr. F. W. Whitehouse exhibited the following fossils:—(1) Flowers of *Williamsonia,* associated with the fronds of *Ptilophyllum,* from the Jurassic deposits (Walloon series) of Bymount, north of Roma; (2) Specimens of a new species of *Calceola* from the Devonian beds of Ukalunda, North Queensland (collected by Mr. J. H. Reid; (3) *Stringocephalus* sp. from the Devonian limestone of Calcium, North Queensland. *Calceola* and *Stringocephalus,* index genera of the Eifelian and Givetian, respectively, of Europe are thus recorded for the first time from Queensland.

Dr. W. H. Bryan exhibited some rather rare rocks from Milford Sound, New Zealand, which had been presented to the University of Queensland by Dr. P. Marshall. The rocks comprised Harzburgite (Saxonite), Dunite, Enstatite, and a perfectly white olivine-carbonate rock. Specimens of Dunite and Harzburgite from the type areas were also shown for purposes of comparison.

Mr. D. A. Herbert exhibited (*a*) *Hydrodictyon reticulatus* from Lake Manchester; (*b*) *Craterium confusum,* a myxomycete from Wooloowin; (*c*) *Ustilago violacea,* a smut fungus attacking *Carex pseudocyperus* from Kuraby; and (*d*) a French bean showing polyembryony. The first three are new records for the State.

Mr. A. K. Denmead exhibited a small fossil identified by Mr. R. A. Keeble as belonging to the family *Diplograptidæ,* from Brisbane schists (Middle of Bunya series), of Tweed Heads. The age was considered to be top of the Ordovician or lowest Silurian.

Mr. J. E. Young exhibited a piece of coral containing a crab-gall produced by the female of *Haplocarcinum marsupialus.*

Mr. C. T. White exhibited specimens of (1) *Ficus Baileyana* Domin. from trees growing in Botanic Gardens, Brisbane. This tree was originally named by F. M. Bailey as *F. macrophylla* Desf. var. *pubescens,* and is related to *F. macrophylla* Desf. on the one hand and to *F. rubiginosa* Desf. on the other, but is distinct from either and seems worthy of specific rank. It is common in cultivation, and specimens are to be found growing in the Botanic Gardens at Brisbane, Sydney, and Adelaide. Both Bailey and Domin record it for the rain-forests of South Queensland, but this, Mr. White thinks, is pure guesswork, as though common in cultivation the plant has not as yet been found in a wild state. Specimens of *F. macrophylla* Desf. and *F. rubiginosa* Desf. were also shown for purposes of comparison; (2) Specimens of a small tree belonging to *Eucalyptus* or allied genus growing on sandy hills at Plunkett. The exact botanical position of this tree is a matter of doubt until flowers have been collected.

Mr. J. B. Henderson exhibited an Analytic Quartz Lamp. This is a mercury vapour lamp so fitted with two Wood's filters that ultra-violet rays are projected horizontally and vertically. The vertical rays fall inside movable black curtains, so that specimens may be examined for fluorescence in daylight. The effect of the ultra-violet rays was shown on various drugs and chemicals, also on papers, minerals, and precious stones.

Mr. C. Morton exhibited specimens of Rutile (red) surrounded by a zone of Ilmenite (black) in rounded as well as roughly crystalline forms up to 2 inches in maximum dimension. They were obtained from shallow alluvial deposits near the Burrandowan road, about 22 miles west of Kingaroy. The country rock is gneissic granite, in which similar specimens were found to occur as isolated individuals.

Dr. E. Marks exhibited two rocks, a trachyte and a tuffaceous conglomerate found at Upper Brookfield.

Dr. Whitehouse, Dr. Bryan, Dr. Marks, and Messrs. White, Jackson, Massey, Denmead, and Jones commented on the exhibits.

Abstract of Proceedings, 27th May, 1929.

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre of the University on Monday, 27th May, 1929, at 8 p.m. The President, Dr. J. P. Lowson, in the chair. Apologies were received from Messrs. Herbert, Perkins, and White. The minutes of the previous meeting were read and confirmed. Miss D. Hill, B.Sc., Miss N. M. Holdsworth, and Mr. L. F. Mandelson, B.Sc., Agr., were unanimously elected to ordinary membership.

Dr. E. O. Marks exhibited water-worn pebbles of trachyte found embedded in sandstone near the summit of Candle Mountain. Dr. E. O. Marks exhibited on behalf of Mr. H. A. Longman aboriginal skulls and showed how they differed in the zygomatic arch from those of whites.

Mr. W. D. Francis, on behalf of Mr. C. T. White, read a résumé of a paper of Dr. C. C. J. van Steenis, entitled "A Revision of the Queensland Bignoniaceæ." Nearly all the Australian members of the family are represented in Queensland. Dr. Steenis makes some changes in nomenclature in agreement with the international rules of nomenclature. He adopts the name Pandorea for the Australian species previously placed under Tecoma. The Queensland species number twelve, and are placed in twelve genera.

Dr. R. Hamlyn-Harris read a paper entitled, "The Relative Value of Larval Destructors and the Part they Play in Mosquito Control in Queensland." Successful experiments with various members of the Characeæ rule these out as possible larvicides. (A jar containing *Nitella phauloteles* (id. by J. Groves), was exhibited to the meeting. *Culex fatigans* in all stages of development, from the eggs to the maturing pupæ, showed perfectly normal conditions, brought about by the larvæ being fed every second day or so on an animal diet, piscidin).

Queensland possesses several mosquitoes cannibalistic in the larval stage, known to be most voracious, two of these, viz., *Lutzia halifaxii* and *Megarhinus speciosus,* are perfectly harmless to human beings, and it is thought that some use might be made of them economically.

There seems to be some diversity of opinion with regard to Tadpoles, and, being for the greater part vegetable feeders, no direct evidence is offered to justify the idea that they devour mosquito larvæ, though investigators in other parts of the world have found certain species useful.

Predatory acquatic Hemiptera may be broadly classed as larval destructors and include effective members of the Gerroidea, Notonectoidea, and Corixoidea. Of even greater value are aquatic Coleoptera (both adults and larvæ) of the super-families Caraboidea, Gyrinoidea, Hydrophilœdæ (in the larval stages only), and Australian Odonata.

In addition to these larval destructors, others include species of Hydra, Hymenoptera, Diptera, Molluscs, and other enemies.

Queensland is particularly fortunate in possessing a large number of larvivorous fish capable of doing good work in fresh, brackish, and salt water. Among these the species most highly recommended are *Craterocephalus fluviatilis* and *Melanotaenia nigrans* for fresh water, and *Pseudomugil signifer* for brackish and salt water. A distinction is drawn between larvivorous fish as surface-feeders and larvæ-eating as bottom feeders of which the Gudgeons are the main representatives. The mortality among fish is due to drought conditions and various enemies, but in spite of this they are nevertheless able to maintain themselves to our advantage and to restock natural waters after periods of flood. Several fish, hitherto overlooked, are here recorded as larval destructors for the first time.

The paper was discussed by Mr. F. Bennett, Dr. E. O. Marks, and Mr. Inigo Jones.

Abstract of Proceedings, 24th June, 1929.

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre of the University on Monday, 24th June, at 8 p.m. The President, Dr. J. P. Lowson, in the chair. An apology was received from Mr. Herbert. The minutes of the previous meeting were read and confirmed. Dr. Ellis Murphy was proposed for ordinary membership.

Mr. G. H. Hardy read extracts from his paper, entitled "Revisional Notes on the Tribe Brachyrrhopalini; with Remarks on the Habits of and Mimicry amongst Robberflies." He discussed the generic alliances of species included in the tribe, and incorporated keys to the five genera and fifteen species constituting the group. Observations on the habits of robberflies indicated the possibility that mimicry amongst robberflies may occur, and evidence may be obtained from the fact that certain species regarded as being wasp mimics have habits differing from those of their nearest allies. Particular attention was drawn to *Erythropogon limbipennis* (Macquart), which does not seem to be predaceous.

Dr. T. G. H. Jones read extracts from his paper on "A Contribution to the Chemistry of the Oily Exudate of the Wood of *Pentaspodon motleyi* (Papua)."

The exudation from the wood of Pentaspodon motleyi on examination has been found to consist essentially of apparently homogeneous acid material, for which the name pentaspodonic acid is proposed. Conclusions as to the constitution of this acid are drawn from various experiments recorded, and it is considered that the acid has a molecular composition $C_{23}H_{34}O_3$. Two unsaturated linkages are present in a long side chain attached to a benzine nucleus. The acid, which is monobasic, also contains one phenolic group.

The Secretary read extracts from the paper by John Legg, D.V. Sc., and J. L. Foran entitled "Some Experiments on Tick-infested Cattle with Arsenical Dipping Fluids." The following took part in the discussion which ensued: Dr. Jones, and Messrs. Pound, Jones, Perkins, Henderson, and Schindler.

Mr. H. A. Longman exhibited a small slab of fossiliferous limestone which had been found by Miss Marion Rowland amongst rocks considerably above high-water mark on Magnetic Island, North Queensland. This slab contained, amongst other remains, several specimens of Barnacles, apparently *Coronula* sp., present-day species of which are found parasitical on whales. Evidently this slab had been detached from its original statum, and if this could be traced it would be of considerable interest.

Mr. Longman also exhibited specimens of the lower jaws of *Macropus anak* and *M. raechus* from the Darling Downs, which he considered were distinct species as indicated by Owen. He could not agree with De Vis in "lumping" both of these under *Macropus anak*.

Abstract of Proceedings, 29th July, 1929.

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre of the University on Monday, 29th July, at 8 p.m. The President, Professor J. P. Lowson, in the chair. Apologies were received from Professor Goddard, Dr. Herbert, and Messrs. Mandelson and Veitch. The minutes of the previous meeting were read and confirmed. Dr. Ellis Murphy was unanimously elected a member of the Society.

The Secretary read extracts from a paper by Dr. John Legg entitled "Some Observations on the Life History of the Cattle Tick."

Dr. W. H. Bryan and Dr. F. W. Whitehouse read a paper entitled "A Record of Devonian Rhyolites in Queensland." The paper reviewed the evidence of the occurrence of Devonian Rhyolites at Kangaroo Hill and Mount Coolon, and placed on record several other rhyolitic series (some of proved Devonian age and others apparently belonging to that period), discovered by one or other of the authors within the last few years, from the following localities:—Herberton, Mount Etna, Tungamull, Mount Morgan, Raglan, Gore.

Dr. W. H. Bryan exhibited: (1) An amethyst-coloured specimen of halite (rock salt) obtained by the Chief Government Geologist (Mr. B. Dunstan) from the Kaiserrode Mine, Borken, Germany; (2) A specimen of decomposed but unweathered granite from the Ashgrove Quarry, Brisbane, containing purple crystals of fluorite associated with quartz and zeolites. This marked the first record of fluorite from the Enoggera Granite.

Abstract of Proceedings, 26th August, 1929.

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre of the University on Monday, 26th August, at 8 p.m. Mr. F. Bennett, B.Sc., in the chair and seven members present. The minutes of the previous meeting were read and confirmed. Mr. H. J. G. Hines, B.Sc., was proposed for ordinary membership by Mr. Perkins, seconded by Dr. Herbert.

Mr. C. T. White, F.L.S., read a paper by himself and Mr. Francis, entitled "Contribution to the Queensland Flora, No. 4." Two new species —*Labichea Brassii* from North Queensland and *Albizzia xanthoxylon* from the Alberton district—were described as new, and several plants were recorded from Queensland for the first time.

Dr. D. A. Herbert read a paper, entitled "Changes in Osmotic Pressure in Relation to Movement of *Mimosa Pudica.*"

Dr. Herbert exhibited (1) *Empusa muscæ,* a fungus causing fly cholera, and (2) *Penicillium expansum,* a mould from a decaying custard apple, also found on the apple.

Mr. C. Schindler exhibited a rust fungus, *Phragmidium longissimum,* on *Rubus parvifolius,* from Mount Crosby.

Abstract of Proceedings, 30th September, 1929.

The Ordinary Monthly Meeting was held in the Geology Theatre on Monday, 30th September, 1929, at 8 p.m.

The President, Professor J. P. Lowson, M.A., M.D., in the chair.

Mr. H. J. G. Hines, B.Sc., was elected to ordinary membership.

Professor E. J. Goddard, B.A., D.Sc., delivered a lecture entitled "Science and Agriculture in Java." A vote of thanks was carried on the motion of Dr. W. H. Bryan, M.C., seconded by the President.

Abstract of Proceedings, 28th October, 1929.

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre of the University on Monday, 28th October, at 8 p.m. Professor J. P. Lowson, M.D., in the chair, and about thirty members present. The minutes of the previous meeting were read and confirmed.

Miss D. Hill, B.Sc., read a paper entitled "The Stratigraphical Relationship of the Shales about Esk." The work indicated that the Esk Shales of the Ipswich coal measures represent closely related phases in a shallow fresh water basin, with but a slight chronological difference. For in effect the Basal Conglomerate of the Ipswich series changes laterally into the highest of the Esk series—the Esk shales. Both these are conformably underlaid by a volcanic stage. The Ipswich coal measure shales thin out rapidly northward and are missing from the basin north of Bellevue, where the overlying Bundamba comes to rest without apparent unconformity on the Esk Shales. The paper was discussed by Professor Richards, Drs. Bryan, Marks, and Whitehouse, and Messrs: Jones, Reid, and Tommerup.

Mr. Inigo Jones exhibited slides of the 1893 flood of the Brisbane River and maps of the area affected.

Dr. F. W. Whitehouse exhibited Bryozoa from the Lower Carboniferous limestones of Riverleigh, near Mundubbera. These included two species of *Archimedes* (genus new to Australia) and one of *Evactinopora* (genus new to E. Australia). The limestone with *Archimedes* contains the *Amygdalophyllum* coral fauna. The *Evactinopora* limestone is probably somewhat higher in the section.

Abstract of Proceedings, 25th November, 1929.

The Ordinary Monthly Meeting was held in the Geology Lecture Theatre of the University on Monday, 25th November, at 8 p.m.

Professor J. P. Lowson, M.D., in the chair, and about thirty members present.

The minutes of the previous meeting were read and confirmed.

Messrs. D. O. Atherton and H. K. Lewcock, M.Sc., were proposed for ordinary membership by Mr. Perkins, seconded by Dr. D. A. Herbert.

Dr. Herbert read a paper entitled "*Cyttaria septentrionalis,*" a new species of fungus attacking the Beech (*Nothofagus Moorei*) in Queensland and New South Wales. This fungus is one of the stromatic Pezizales, and the genus is found in South America, New Zealand, and Tasmania, on various species of *Nothofagus*. The new species extends the range of the genus to Queensland, and makes the range practically that of the host genus. The specimens were collected by Mr. C. T. White (Government Botanist) and by the author at different times on Mount Hobwee in National Park, on the New South Wales border. It is limited to a few acres of beeches on the mountain top, and seems to be confined to the portion of the mountain commonly enveloped in clouds. It is edible, as are other species of the genus.

A discussion of the paper, in which Drs. Bryan, Marks, Whitehouse, and Messrs. Bennett, Jones, and Perkins took part, developed on the bearing of this and other evidence on the Wegener hypotheses.

Publications have been received from the following Institutions, Societies, etc., and are hereby gratefully acknowledged.

AFRICA.

ALGERIA—

Société de Géographie et d'Archéologie d'Oran, Oran.

UNION OF SOUTH AFRICA—

Durban Museum, Natal.

South African Museum, Capetown, Cape Province.

Transvaal Museum, Pretoria.

Geological Society of South Africa, Johannesburg.

AMERICA.

ARGENTINE—

Museo de la Plata, Universidad Nacional de la Plata.

BRAZIL—

Instituto Oswaldo Cruz, Rio de Janeiro.

Ministerio de Agricultura, Industria y Commercio, Rio de Janeiro.

CANADA—

Department of Agriculture, Ottawa.

Department of Mines, Ottawa.

Nova Scotia Institute of Science, Halifax, Nova Scotia.

Royal Society of Canada, Ottawa.

Royal Astronomical Society of Canada, Toronto.

Royal Canadian Institute, Toronto.

UNITED STATES OF AMERICA—

Bingham Oceanographic Institute, San Diego.

Florida Geographical Society.

Carnegie Institution, Washington.

Library of Congress, Washington.

National Academy of Sciences, Washington.

National Research Council, Washington.

Smithsonian Institution, Washington.

United States Department of Agriculture, Washington.

United States Department of Commerce (Bureau of Standards), Washington.

United States Department of the Interior (United States Geological Survey), Washington.

United States National Museum, Washington.

United States Treasury (Public Health Service).

Lawde Observatory, Arizona.

Scripps Institute of Oceanography, La Jolla, U.S.A.

University of California, Berkeley, California.

John Hopkins University (Institute of Biological Research), Baltimore.

American Academy of Arts and Sciences, Boston.

Boston Society of Natural History, Boston.

Buffalo Society of Natural Science, Buffalo.

John Crerar Library, Chicago.

Field Museum of Natural History, Chicago.

Lloyd Library, Cincinnati.

Ohio Academy of Science, Columbus.

Ohio State University, Columbus.

Bernice Pauahi Bishop Museum, Honolulu.

Natural History Survey, State of Illinois.

Indiana Academy of Science, Indianapolis.

Cornell University, Ithaca, N.Y.

Cornell University Agricultural Experiment Station.

Arnold Arboretum, Jamaica Plain, Massachusetts.

Wisconsin Academy of Arts, Science, and Letters, Madison.

Michigan Academy of Arts, Science, and Letters, Michigan.

University of Michigan, Michigan.

Minnesota Geological Survey, Minneapolis.

University of Minnesota, Minneapolis.

New York Academy of Sciences, New York.

American Geographical Society, New York.

American Museum of Natural History, New York.

Bingham Oceanographic Collection, New York.

New York Zoological Society, New York

Oberlin College, Ohio.

Academy of Natural Sciences, Philadelphia.

American Philosophical Society, Philadelphia.

Portland Society of Natural History.

Rochester Academy of Sciences, Rochester.

San Diego Society of Natural History, San Diego.

California Academy of Sciences, San Francisco.

Puget Sound Biological Station, Seattle.

Missouri Botanic Garden, St. Louis.

University of Illinois, Urbana.

University of Kansas, Laurence, Kansas.

MEXICO—

Instituto Geologico de Mexico, Mexico.

MEXICO—*continued.*

Sociedad Cientifica, "Antonio Alzate," Mexico.

Observatorio Meteorologico Central, Tacaibaya, D.F., Mexico.

Secretario de Agricultura y fomento, San Jacinto, D.F., Mexico.

PERU

Sociedad Geologico, del Peru, Apartado de Corres No. 1659, Lima, Peru.

ASIA.

CEYLON—

Colombo Museum, Colombo.

INDIA—

Agricultural Research Institute, Pusa.

Government of India—

Department of Agriculture.
Geological Survey.
Superintendent, Government Printing.

Punjab University.

Indian Academy of Science.

JAPAN—

Imperial University, Kyoto.

Imperial University, Tokyo.

National Research Council of Japan, Euno, Tokyo.

JAVA—

Koninklijke Naturkundige, Batavia.

Department van Landbouw, Buitenzorg.

PHILIPPINE ISLANDS—

Bureau of Science, Manila.

College of Agriculture, University of the Philippines, Manila.

AUSTRALIA AND NEW ZEALAND.

COMMONWEALTH—

Australian Commonwealth Engineering Standards Association, 16 College Street, Sydney.

Commonwealth Department of Health, Spring Street, Melbourne.

Council for Scientific and Industrial Research, 314 Albert Street, East Melbourne.

QUEENSLAND—

Department of Agriculture, Brisbane.

Department of Mines, Brisbane.

Queensland Geological Survey, Brisbane.

Queensland Museum, Brisbane.

Queensland Naturalists' Club, Brisbane.

Royal Geographical Society of Australasia (Queensland), Turbot Street, Brisbane.

State Statistician, Brisbane.

NEW SOUTH WALES—

Australasian Association for the Advancement of Science, Royal Society's Hall, Elizabeth Street, Sydney.

Department of Agriculture, N.S.W.

Botanic Gardens, Sydney.

Geological Survey of N.S.W., Sydney.

Public Library; Sydney.

Linnean Society of N.S.W., 16 College Street, Sydney.

Australian Museum, College Street, Sydney.

Royal Society of N.S.W., Royal Society House, Elizabeth Street, Sydney.

Naturalists' Society of N.S.W., Box 2178 L.L., G.P.O., Sydney.

University of Sydney.

VICTORIA—

Bureau of Census and Statistics, Melbourne.

Royal Society of Victoria, Victoria Street, Melbourne.

Field Naturalists' Club, Royal Society's Hall, Victoria Street, Melbourne.

Department of Agriculture, Melbourne.

Department of Mines, Melbourne.

Australasian Institute of Mining and Metallurgy, Melbourne.

Australian Veterinary Association, Melbourne.

TASMANIA—

Royal Society of Tasmania, Hobart.

Field Naturalists' Club, Hobart, Tasmania.

Geological Survey of Tasmania.

SOUTH AUSTRALIA—

Department of Mines, Adelaide.

Royal Society of South Australia, Adelaide.

Royal Geographical Society of South Australia, Adelaide.

National Museum of South Australia, Adelaide.

Geological Society of South Australia, Adelaide.

Public Library, Museum, and Art Gallery, Adelaide.

University of Adelaide.

Waite Institute, Glen Osmond.

WESTERN AUSTRALIA—

Royal Society of Western Australia, Perth.

Geological Survey of Western Australia, Perth.

NEW ZEALAND—

Auckland Institute, Auckland.

New Zealand Board of Science and Art.

Dominion Laboratory, Wellington.

Geological Survey of New Zealand.

New Zealand Institute, Wellington.

Dominion Museum, Wellington.

EUROPE.

League of Nations, Geneva.

AUSTRIA—

Natural History Museum, Vienna.

BELGIUM—

Academie Royale, Bruxelles.

Société Royale de Botanique de Belgique, Bruxelles.

Société Royale Zoologique de Belgique, Bruxelles.

CZECHO-SLOVAKIA—

Spolecnosti Entomologické, Prague.

Plant Physiological Laboratory, Charles University, Prague.

DENMARK—

The University, Copenhagen.

FRANCE—

Société Botanique de France, Paris.

Société Geologique et Mineralogique de Bretagne, Rennes.

Société des Sciences Naturelles de l'Ouest, Nantes.

Musée d'Histoire Naturelle, Paris.

L'Observatoire de Paris.

Station Zoologique de Cette (Université de Montpelier), Cette.

Société de Geographie de Rochefort.

Observations Météorologiques de Mont Blanc.

Office Scientifique des Pêches Maritimes.

GERMANY—

Naturwissenschaftlichen Verein, Bremen.

Bibliothek der B., Akademie der Wissenschaften, Munich.

Notgemeinschaft der Deutschen Wissenschaft, Berlin.

Senckenbergischen Bibliothek, Frankfurt, A.M.

Naturhistorischer Verein der preus Rheinland und Westfalens, Bonn.

Sachs Akademie der Wissenschaften, Leipzig.

Deutsche Geologische Gesellschaft, Berlin.

Zoologischen Staatsinstitut and Zoologischen Museum, Hamburg.

Gesellschaft für Erdkunde, Berlin.

Centralblatt für Bakteriologie, Parasitenkunde and Infectionskrankheiten.

Feddes Repertorium, Fabelk Stresze, 49 Dahlem, Berlin.

Zooloogische Museum, Invaliden Strasz, 43 Berlin N. 4.

Institut fur Weltwirtschaft and Seeverkehr, University of Kiel.

Kaiserliche Leopold Deutsch Akadamie der Naturforther, Friedrich Strasze, 50A Halle.

GREAT BRITAIN—

Cambridge Philosophical Society.

Conchological Society of Great Britain and Ireland.

Imperial Bureau of Entomology, 41 Queen's Gate, London.

Literary and Philosophic Society, Manchester.

Royal Society of London, Burlington House.

Royal Botanic Gardens, Kew, Surrey, England.

Royal Colonial Institute, Northumberland Avenue, London.

Royal Society of Edinburgh.

Botanic Society of Edinburgh.

Royal Irish Academy, 19 Dawson Street, Dublin.

British Museum (Natural History), Cromwell Road, London, S.W.

Royal Dublin Society, Ballsbridge, Dublin.

HOLLAND—

Technische Hoogeschool, Delft.

ITALY—

Societa Africana d'Italia, Naples.

Instituto di Bologna.

Societa Toscana di Scienze Naturali, Pisa.

Museo Civico, Genova.

NORWAY

Tromso Museum, The Library, Tromso.

POLAND—

University of Poland, Warszawa (Varsovie).

L'amon des Sociétés Savantes Polonaises.

PORTUGAL—

Academia Polytechnicada, Oporto.

Universidade de Coimbra: Instituto Botanico (Sociedade Broteriana), Coimbra.

Instituto Botanico, Coimbra.

SPAIN—

Real Academia de Ciencias de Madrid.

Real Academia de Ciencias de Barcelona.

Academia de Ciencias de Zaragoza.

Museo de Historia Natural, Valencia.

SWEDEN—

Geological Institute of Upsala University, Upsala.

SWITZERLAND—

Naturforschende Gesellschaft, Basle.

Naturforschende Gesellschaft, Zurich.

Société de Physique et d'Histoire Naturelle, Geneva.

List of Members.

CORRESPONDING MEMBERS.

David, Professor, Sir T. W. E., F.R.S. ... The University, Sydney, N.S.W.
‡Domin, Dr. K. ... ... Czech University, Prague.
‡Maitland, A. Gibb, F.G.S. ... ... Melville Place, S. Perth, W.A.
‡Skeats, Professor E. W. ... ... The University, Melbourne, Vic.

ORDINARY MEMBERS, ETC.

Bage, Miss F., M.Sc. ... ... Women's College, Kangaroo Point, Brisbane.
†Bagster, L. S., D.Sc. ... ... The University, Brisbane.
†‡Bailey, J. F. ... ... Botanic Gardens, Adelaide, S.A.
Ball, L. C., B.E. ... ... Geological Survey Office, Brisbane.
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Barker, G. H. ... ... Adelaide street, Brisbane.
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Cilento, R. W., M.D., B.S. ... ... Steamship Chambers, Eagle Street, Brisbane.
Colvin, Joseph ... ... Technical College, George Street, Brisbane.

† Life Members.
‡ Members who have contributed papers to the Society.

Cottrell-Dormer, W.	University, Brisbane.
Cowley, R. C.	Pharmacy College, Brisbane.
Crawford, Miss L.	Children's Hospital, Brisbane.
Croll, Gifford, M.B.	Sherwood, Brisbane.
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Graff, R., M.B., B.S.	Alpha District Hospital.
‡Grey, Mrs. B. B., F.L.S.	care of Queensland Trustees, Ltd., Margaret Street, Toowoomba.
Greene, Miss A.	High School, Wynnum.
‡Gurney, E. H.	Agricultural Chemist's Laboratory, William Street, Brisbane.
‡Hamlyn-Harris, R., D.Sc.	Town Hall, Brisbane.
Hardie, Sir David, M.D., M.S.	"Blythsdale," Hamilton, Brisbane.
‡Hardy, G. H.	Biology Department, The University, Brisbane.
Harris, V. E. G., B.Sc.	The Southport School, Southport.
‡Hawken, Professor R. W., B.A., M.E., M.Inst.C.E.	The University, Brisbane.
‡Henderson, J. B., F.I.C.	Government Analyst, Brisbane.
‡Herbert, D. A., D.Sc.	The University, Brisbane.
Herdsman, L. P.	Government Printing Office, George Street, Brisbane.
Hill, J., B.Sc., A.R.C.S.	Department of Public Instruction, Brisbane.
‡Hill, Miss D., B.Sc.	Geology Department, University, Brisbane.
Hines, H. J., B.Sc.	University, Brisbane.
Holdsworth, Miss N.	Women's College, Kangaroo Point, Brisbane.
Hitchcock, L. F., B.Sc.	Prickly-pear Laboratory, Brisbane.

† Life Members.

‡ Members who have contributed papers to the Society.

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Holdaway, F. G., M.Sc.	Department of Zoology, The University, Adelaide, S.A.
Hubbard, Rev. W. P. H.	St. Alban's Rectory, Innisfail.
‡Hull, A. Bassett	Box 704, G.P.O., Sydney.
†Hulsen, R.	Valley Corner, Brisbane.
Irving, C. R., B.A.	State School, Caboolture.
Jack, Thos.	Cunningham Street, Dalby.
Jackson, A. G.	Synchronome Co., Elizabeth Street, Brisbane.
‡Jensen, H. I., D.Sc.	Treasury Chambers, George Street, Brisbane.
Jones, Miss G.	Children's Hospital.
Jones, A. J.	Parliament House, Brisbane.
Jones, Inigo	Bower Street, off Gladstone Road, South Brisbane.
‡Jones, Owen, M.Sc.	Sydney Street, Eagle Junction, Brisbane.
‡Jones, T. G. H., D.Sc., A.A.C.I.	Chemistry Department, The University, Brisbane.
Jorgensen, G. H.	care of Australian Chemical Co., Grey Street, South Brisbane.
Just, J. S.	Royal Exchange Buildings, Eagle Street, Brisbane.
Kelly, N. L., B.Sc.	care of Department of Agriculture and Stock, Brisbane.
Kemp, J. R.	Main Roads Commission, Desmond Chambers, Adelaide Street, Brisbane.
Kerr, W. H., Ph.D., M.Sc.	" Kilmours," Edward Street, Toowong.
‡Lambert, C. A.	care of Bank of N.S.W., Melbourne, Vic.
Lane, N. C., M.B., B.S.	59 Wharf Street, Brisbane.
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