PROCEEDINGS

OF THE

ROYAL SOCIETY

OF

QUEENSLAND

FOR 1952

VOL. LXIV.

ISSUED 5th APRIL, 1954.

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HIS EXCELLENCY LIEUT-GENERAL SIR JOHN D. LAVARACK, C.B., C.M.G., D.S.O., C. de G., K.B.E.

OFFICERS, 1952.

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2. Papers must be complete and in a form suitable for publication when communicated to the Society and should be as concise as possible. All calculations, figures, tables, names, quotations and references to literature should be carefully checked.

3. The use of italics in the text should be restricted to the names of genera and groups of lower rank, foreign words and titles of periodicals.

4. Except in taxonomic papers, all references should be listed at the end of each paper and arranged alphabetically under authors' names, *e.g.*

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   Kelley, T. L., 1923. Statistical Method. New York, Macmillan Company. XI+390 pp., 24 fig.

   The corresponding references in the text should take one of the following forms :—

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Proceedings of the Royal Society of Queensland.

PRESIDENTIAL ADDRESS.

SOME BIOCHEMICAL ASPECTS OF REACTIONS TO HEAT AND COLD.

By H. J. G. Hines, Department of Physiology and Biochemistry, University of Queensland.

(*Delivered before the Royal Society of Queensland*, 31*st March*, 1952.)

The department with which I am associated has, since its inception in 1936, made the study of the reactions of man and animals to environmental conditions its special business (Yeates, Lee and Hines, 1941). It is the business of the physiologist to study the working of animals and plants as a whole. To do this he must often study the functions of parts whether *in situ* or detached from the animals. It is the function of the biochemist to study the events of the living process at the molecular level. There is often a considerable gap between these two processes since the working out of biochemical details usually lags behind the general overall picture of physiological behaviour.

I shall therefore endeavour to show how this gap is being filled, as yet, of course, incompletely, with respect to the effects of climatic conditions on man and animals. I can assume that we are all familiar with the distinction between warm-blooded and cold-blooded animals, or to use more technical jargon, the homoiotherms and the poikilotherms. The former group, which comprises the mammals and birds, is able to maintain a relatively constant internal temperature which is usually above that of the environment, while the internal temperature of the poikilotherms rises and falls with that of the surroundings. I want to concern myself with homoiothermic animals, the maintenance of whose internal temperature requires the generation of sufficient heat to balance that which is lost to the environment, and also requires mechanisms to regulate the production and loss of heat. The main features of this process were clearly established during the nineteenth century, and accounts given in text books written fifty years ago can still be read with profit.

The production of animal heat was, of course, a mystery to the ancients and its true nature had to await the investigations of Lavoisier in France and of Crawford in Scotland in the latter part of the eighteenth century. With the discovery of the true nature of combustion, Lavoisier was quick to recognise the essential similarity between combustion and respiration, the consumption of oxygen and the output of carbon dioxide. He was able to measure the gaseous exchange quite accurately and went on to measure the heat output of small animals with his ice calorimeter. He realised the defects of this apparatus and in particular noted that the heat output of the animal increased in the cold. Crawford, and later Duboy and Despretz were able to make improved measurements. Animal heat was clearly produced in the process of oxidation of the food consumed. During the succeeding century nearly every physiologist of note had something to say of this problem, touching as it did on almost all aspects of physiology, and the investigations of the great German physiologists, Voit, Pettenkofer and Rubner clearly established the energetic equivalence of food consumed and heat and work produced. Throughout this time, the nature of the oxidative process remained a mystery. Lavoisier thought that combustion took place in the lungs, but later experiments showed that oxygen was consumed and carbon dioxide was produced in all parts of the body and that the amounts were greatly increased by muscular exertion. A recent calculation gives the following estimate of the heat produced by the tissues of a man under basal conditions.

TABLE I*.

—	Weight of Organ and (Proportion of Body Weight).	Oxygen Consumption of Organ. Litres O_2/24 hr. and Proportion of Total Oxygen Consumption.	Heat Produced Kg. Cal./24 hr./Kg. Tissue.
Whole Body	70 Kg. (100%)	356 (100%)	23·5
Heart	0·33 Kg. (0·47%)	37 (10%)	520
Kidneys	0·33 Kg. (0·47%)	31 (9%)	440
Liver	1·6 Kg. (2·3%)	115 (32%)	335
Brain	1·4 Kg. (2%)	68·5 (19%)	225
	3·66 Kg. (5·24%)	251·5 (70%)	
Rest of Body (by difference)	66·3 Kg. (94·7%)	105 (30%)	7·4
Muscles	29·5 Kg. (42%)	58·5 (16%)	9·2

* This table is taken from Mr. Hedley Marston's Liversidge Lecture (Marston 1951).

The term 'basal conditions' used in this connection may require a little explanation. When an animal fasts, the food in its alimentary canal is quickly used up and it is forced to live on its own reserves, the protein and fat of its tissues. Oxygen consumption, carbon dioxide production, and with them heat production, fall to a minimum value which forms an important base line, the 'basal metabolism,' well known in all nutritional studies. Under external conditions, generally spoken of as thermoneutral, the basal metabolism is held to represent the minimum energy expenditure necessary to sustain life.

The table shows that most of the energy exchange under these conditions occurs in a central 'core'. Particularly noteworthy is the high oxygen consumption of liver and brain. Organs which between them constitute only five per cent. of the body weight, are responsible for seventy per cent. of the heat production. The liver, of course, is the great factory and warehouse, receiving most of the products of digestion and converting them into products suitable for use in other tissues. The multiplicity of its chemical functions makes it a happy hunting ground for the biochemical investigator.

The way in which oxidation is effected in the tissues remained unknown in the nineteenth century. Quite obviously, the change from such a substance as sugar to carbon dioxide and water was not sudden. The patient unravelling of the mechanisms of oxidation in the tissues has been a major occupation of biochemists during the past thirty years. The operation proceeds stepwise through a series of intermediates. Linked with these steps is another process, the transfer of phosphoric acid. The energy released by the dismutation and oxidation of sugars, fats, and other substances is transferred to compounds of phosphoric acid, and in particular is used in forming the substance adenosine triphosphate. The anhydride linkages in this substance serve as a kind of energy currency. Simple hydrolysis of the linkage merely dissipates chemical energy as heat, but the energy of fission can be directly utilized for a variety of purposes; the contraction of muscle, the generation of electricity, the movement of substances along concentration gradients, the synthesis of complex molecules, all derive the necessary energy through transfer of phosphoric acid from these unstable compounds of phosphoric acid. The process appears universal in plants and animals, and its discovery is one of the major biochemical achievements of the past twenty-five years. Animals therefore are not heat engines. They do not convert heat energy into mechanical energy, but achieve the transfer of chemical energy in a variety of ways. In all such transfers a part of the energy is lost as heat energy, and if the animal is not performing external work, eventually all the energy

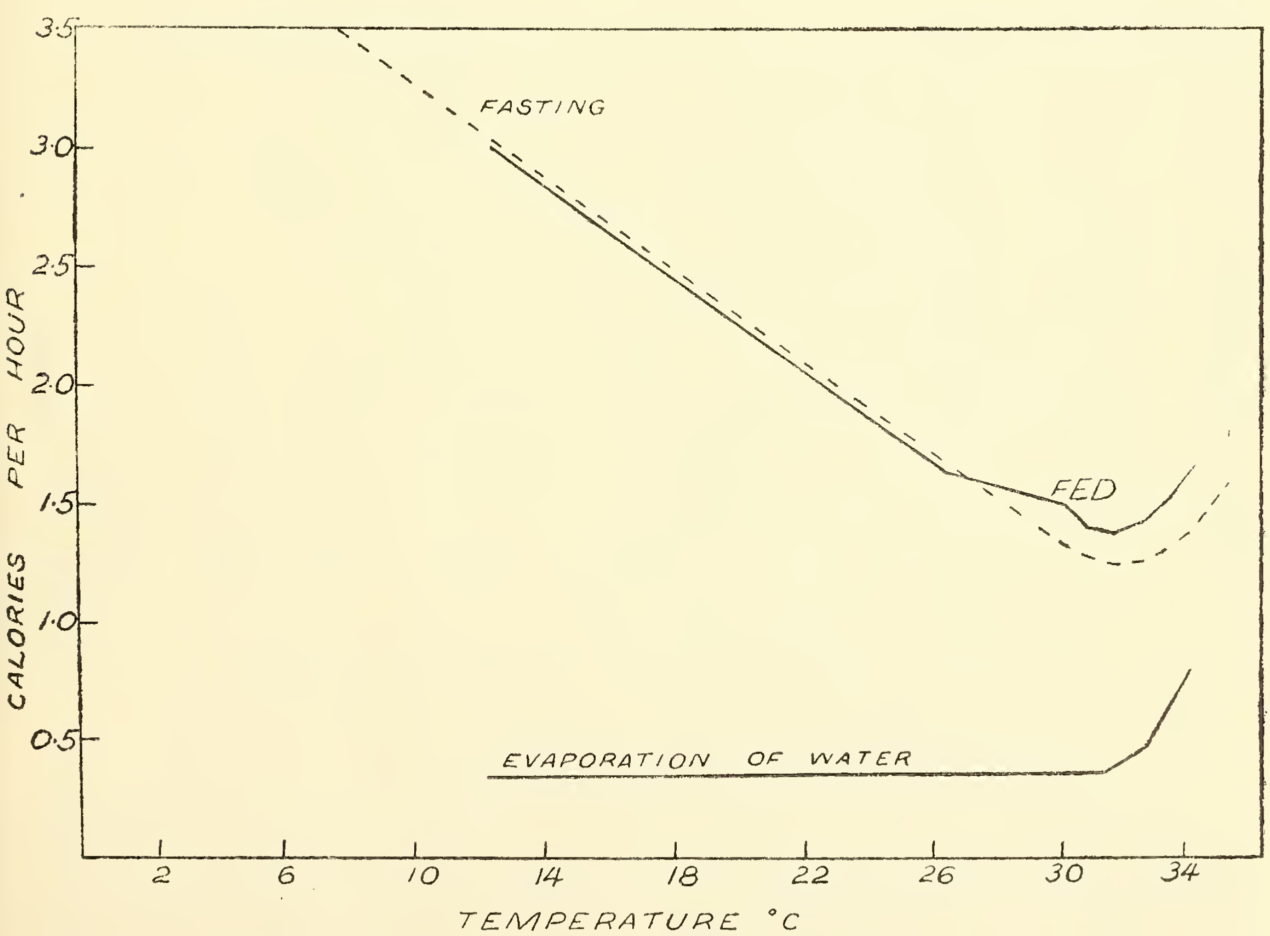

Fig. 1. Comparison of the heat production of fasting albino rats with that of animals receiving feed at different environmental temperatures.

resulting from oxidation appears as heat. Such heat energy is useful to the animal only in so far as it serves to maintain body temperature above that of the surroundings.

From the earliest investigations it was made clear that down to a certain environmental temperature (the critical temperature), the body temperature could be maintained without increasing the metabolism, simply by increasing the insulation (so called physical heat regulation). Below the critical temperature, the body temperature could be maintained only by increasing the heat production (so-called metabolic or 'chemical' heat regulation). A great many experiments have been conducted to determine this critical temperature for a variety of animals. A typical experiment with that favourite laboratory animal, the albino rat, is shown in Fig. 1 (Black and Swift, 1943).

In this rather pampered animal, the range of thermoneutrality is limited to a degree or so, and the heat production rises linearly with decrease in temperature. Note that above the critical temperature, or critical thermal environment, heat production also rises.

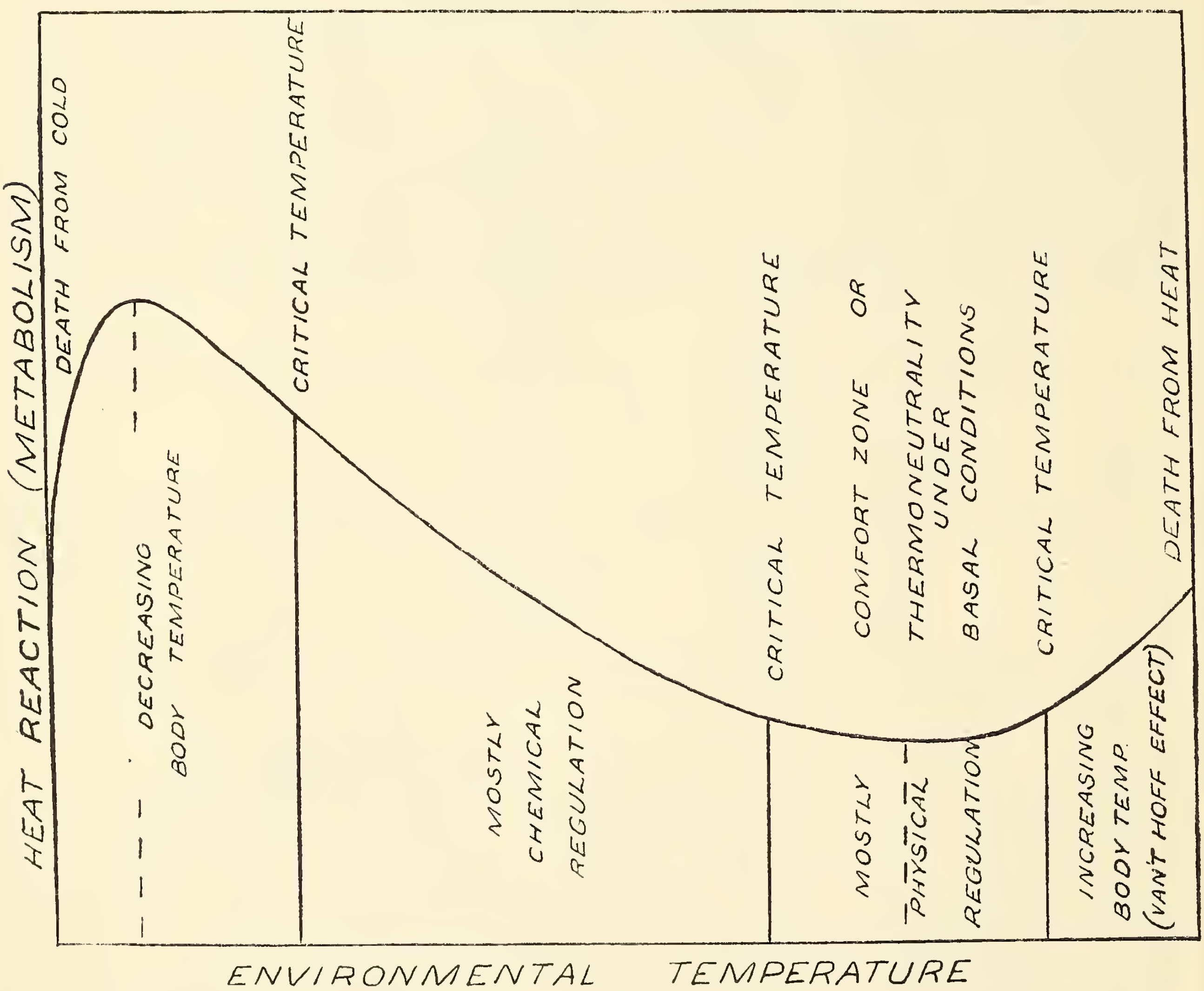

Fig. 2. Influence of environmental temperature on heat production.

Figure 2 (Brody, 1945) serves to illustrate features common to all homoiotherms. If the environmental conditions are such that heat production can no longer keep pace with heat loss, and 'body temperature' falls and the animal may die. In man, a rectal temperature of 25°C. seems to be the lowest consistent with survival, but other animals can drop to still lower temperatures and survive. The hibernating animals during hibernation resemble cold-blooded animals and the rectal temperature may fall to as low as 2°C. with metabolism almost at a standstill.

Strictly speaking then, the term homoiotherm as applied to mammals and birds is a misnomer. Life can continue over quite a range of temperature, but the range is greater below the critical temperature than above it.

At this stage I should like to draw your attention to the comprehensive studies on arctic and tropical birds and mammals recently published by Scholander (1950) and his associates. They were able to carry out experiments at Point Barrow, Alaska, latitude 71°N., and in the Panama Canal zone at latitude 9°N. Metabolic rates for a number of animals were determined at different environmental temperatures, and striking differences were shown in the behaviour of the arctic and tropical groups. The arctic animals were able to maintain constant body temperatures without increase in metabolic rate. There is no evidence of adaptive low body temperature in arctic mammals and birds, or high body temperature in the tropical species. There are no signs so far that body temperatures of mammals and birds are adaptive to the different climates on earth. A logical corollary of this is that they cannot have been adaptive to the overall climatic conditions on earth. It seems then that the narrow band of body temperatures on which both birds and mammals operate is a fundamental, non-adaptive constant in their biochemical set-up. This shows that the striking differences in critical temperatures, and increased rates of heat production below critical temperatures, are largely a matter of insulation in the broad sense, that is, in resistance to heat dissipation (Fig. 3).

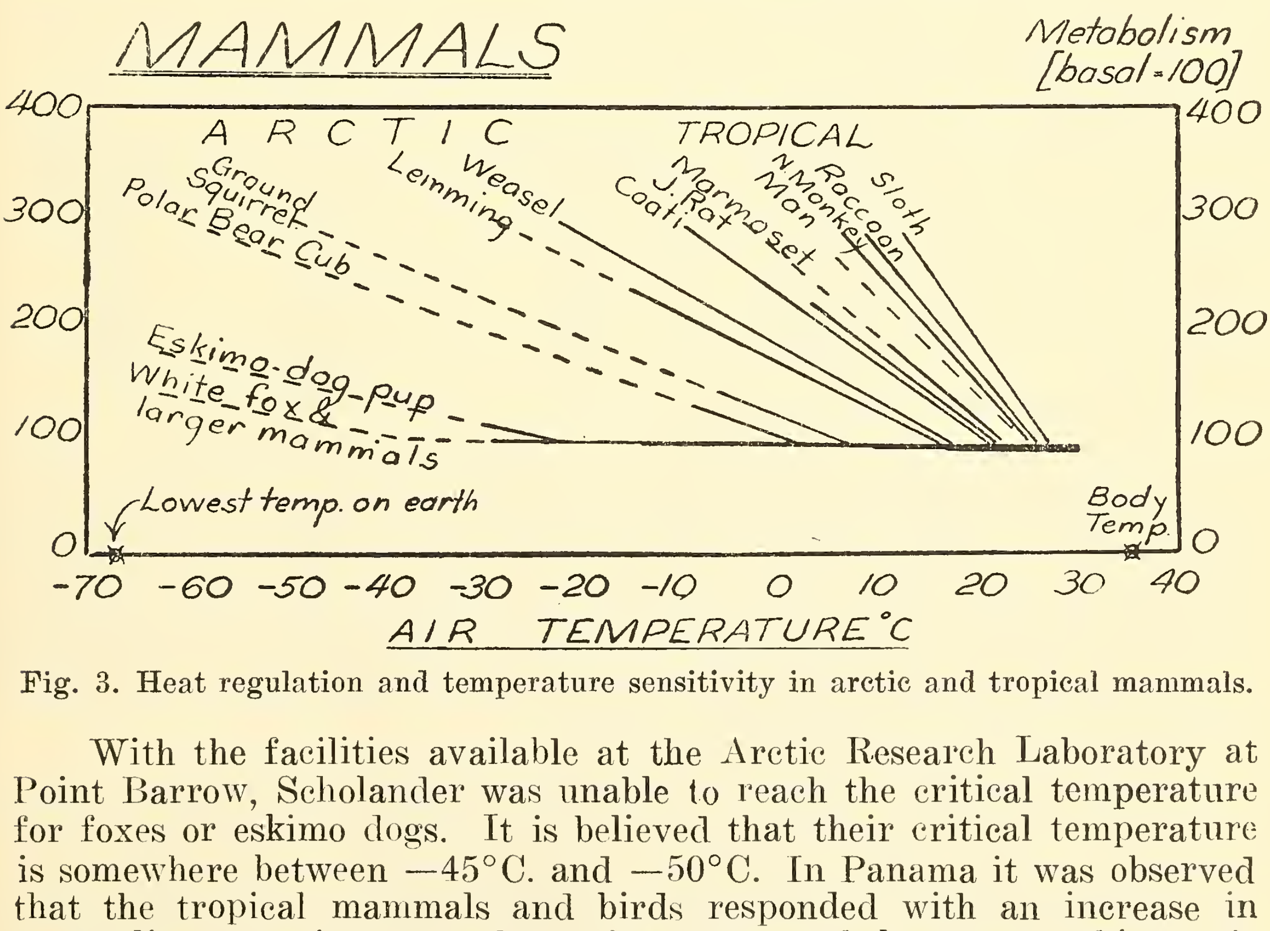

Fig. 3. Heat regulation and temperature sensitivity in arctic and tropical mammals.

With the facilities available at the Arctic Research Laboratory at Point Barrow, Scholander was unable to reach the critical temperature for foxes or eskimo dogs. It is believed that their critical temperature is somewhere between —45°C. and —50°C. In Panama it was observed that the tropical mammals and birds responded with an increase in metabolism starting at only a few degrees below the ambient air temperature, producing strikingly steep curves compared with those of the arctic animals.

The critical temperature in naked man is known to be around 27°C. to 29°C., which places him among the more temperature sensitive of the tropical mammals. The Australian aboriginal however, seems to be exceptional in that he can apparently lie naked and at rest at temperatures near to freezing point without increasing his metabolic rate. There appears to be a fall in body temperature, however, and the aborigine's behaviour on waking bears some resemblance to that of a hibernating animal. The point that emerges from these investigations is that the basal metabolic rate of terrestrial mammals from tropics to arctic is fundamentally determined by a size relation according to the formula Cal./day=70 $Kg^{\frac{3}{4}}$, and is phylogenetically non-adaptive to external temperature conditions. Equally non-adaptive is the body temperature, and the phylogenetic adaptation to cold therefore rests entirely upon the plasticity of the factors which determine the heat loss.

The basal heat production we have seen, arises largely from the activity of the visceral organs and the brain. The muscles contribute a relatively small amount. Below the critical temperature, however, when conditions are no longer basal, the extra heat production is brought about largely through muscular movement, both voluntary and involuntary. The survival of an animal exposed to cold obviously depends on whether this extra heat production can balance the heat loss, and the duration of this extra heat production will determine survival. This in turn will depend on the rate supply of nutrients to the metabolising tissues and the rate of utilization. The rapidity with which liver glycogen is used by pigeons subjected to cold is shown by the following table (adapted from Streicher, Hackel and Fleischmann, 1950).

TABLE II.

Duration of Experiment in Hours.	At −40°C.		At 23°–25°C.	
	Liver Glycogen %.	Blood Sugar mg.m/100ml.	Liver Glycogen %.	Blood Sugar mg.m/100ml.
1	1·48	147	1·31	152
3	0·84	143	1·54	147
8	0·05	158	0·76	154
24	0·002	135	0·043	154
48	0·015	129	0·108	141
72	0·0	159	0·005	151

In eight hours the liver glycogen of the birds kept fasting at —40°C. was almost exhausted. After 24 hours that of the control group was almost zero. The metabolic rate of the birds exposed to cold was approximately three times that of the birds in the control group. The blood sugar on the other hand stays constant, and this implies the efficient conversion of non-sugars to sugar. The survival of the birds will depend on the availability of body reserves of protein and fat and the rate at which they can be oxidised.

That metabolic demand may outstrip exogeneous supply in fully fed animals is also shown by the experiments of Black and Swift (1943) on rats. With decreasing external temperatures, their experiments showed that the respiratory quotient fell as the metabolic rate rose. A curious point is that the respiratory quotient also fell with the rise in metabolic rate above the critical temperature. The following table is taken from their paper.

TABLE III.

Temperature.	Respiratory Quotient.	Total Heat/hr.
°C.		
12	0·837	3·00
18	0·859	2·40
24	0·902	1·79
28	0·948	1·59
30	0·946	1·50
31	0·951	1.38
32	0·942	1·38
33	0·915	1·45
34	0·918	1·61

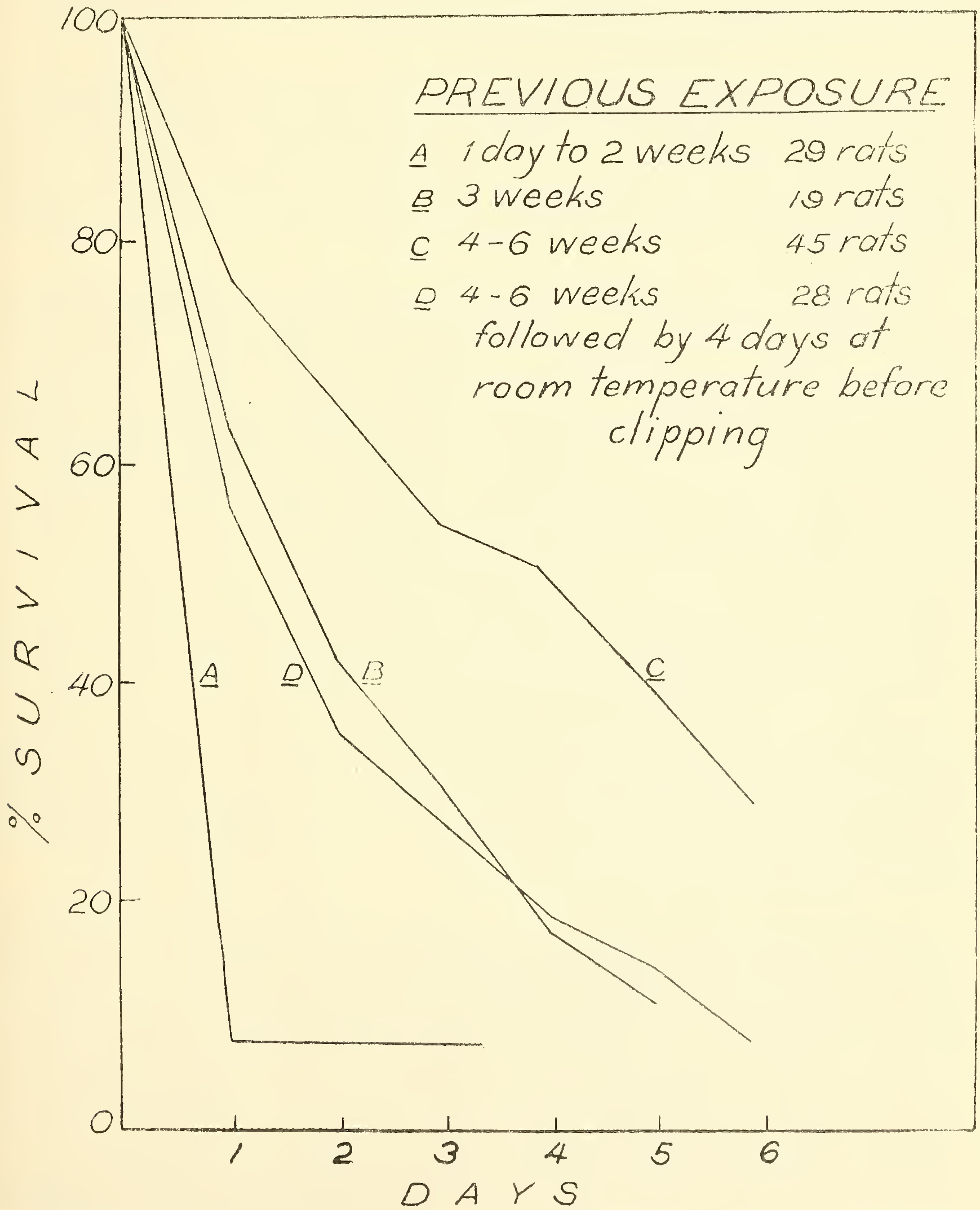

Fig. 4. Survival of clipped rats at 1·5°C. after periods of previous exposure.

A respiratory quotient of unity in an experiment lasting 7½ hours may be taken to indicate that carbohydrate is being consumed whilst the R.Q. of fat is 0.7.

It has been shown, however, that rats can gradually undergo adaptive changes to cold which increase their resistance to this form of stress. The 'acclimatisation,' if such it can be called, is related to the ability of the animal to maintain a high level of metabolic activity for prolonged periods. This relationship has been shown by clipping the fur of normal and acclimatised rats and exposing them to cold. Acclimatised animals survive and maintain greatly increased metabolic rates for significantly longer periods than do animals which are unaccustomed to lowered environmental temperatures. The effects of varying exposure on survival time are shown in figure 4 (Sellers, Reichman and Thomas, 1951).

The conclusions drawn from these figures are that the process of acclimatisation to cold is gradual. No effect is noticed before two weeks of exposure, but it is fully developed after four to five weeks and does not increase further. The altered metabolic state is not permanent and may be rapidly lost after a return to a warm environment.

There is ample evidence that hormonal factors are implicated in some of the changes which take place during exposure to cold. The pituitary, the adrenal and the thyroid glands all undergo alterations in size and in function during exposure. Indeed, there is evidence that survival at temperatures near zero is dependent on the presence of these glands. The relationship of the endocrine glands to acclimatisation is not a simple one, however, for it has been shown that acclimatised animals subjected to adrenalectomy survive longer in the cold than do non-acclimatised adrenalectomised controls. A similar relationship has also been established with respect to the exposure of thyroidectomised animals to cold. These observations, taken in conjunction with the finding that acclimatisation develops gradually, suggest that metabolic tissues themselves undergo some adaptive alteration, perhaps in response to a general controlling influence. Note that these changes are temporary and are not to be confused with phylogenetic adaption to temperature. Sellers, Reichmann and Thomas (1951) attempted to prolong survival 'artificially' by pretreatment with cortisone and thyroxine and with other substances. The use of a combination of cortisone and thyroxine given before clipping and exposure to cold significantly increased survival (Fig. 5).

The recognition of the part played by the hormones of the suprarenal in the maintenance of homeostasis has been one of the most striking features of the physiology of the past decade. Earlier emphasis on the sympatho-adrenal system has been followed by the discovery of the even more ubiquitous part played by the pituitary and adrenal cortex. "The sympatho-adrenal system actively drives organs and organ systems to increased functional activity in emergencies, whereas the pituitary-adrenocortical system plays a passive role, making cortical hormone available in quantities appropriate for the varying needs of the organism. In other words, the sympatho-adrenal system initiates, whereas the pituitary-adrenocortical system supports cellular activities."

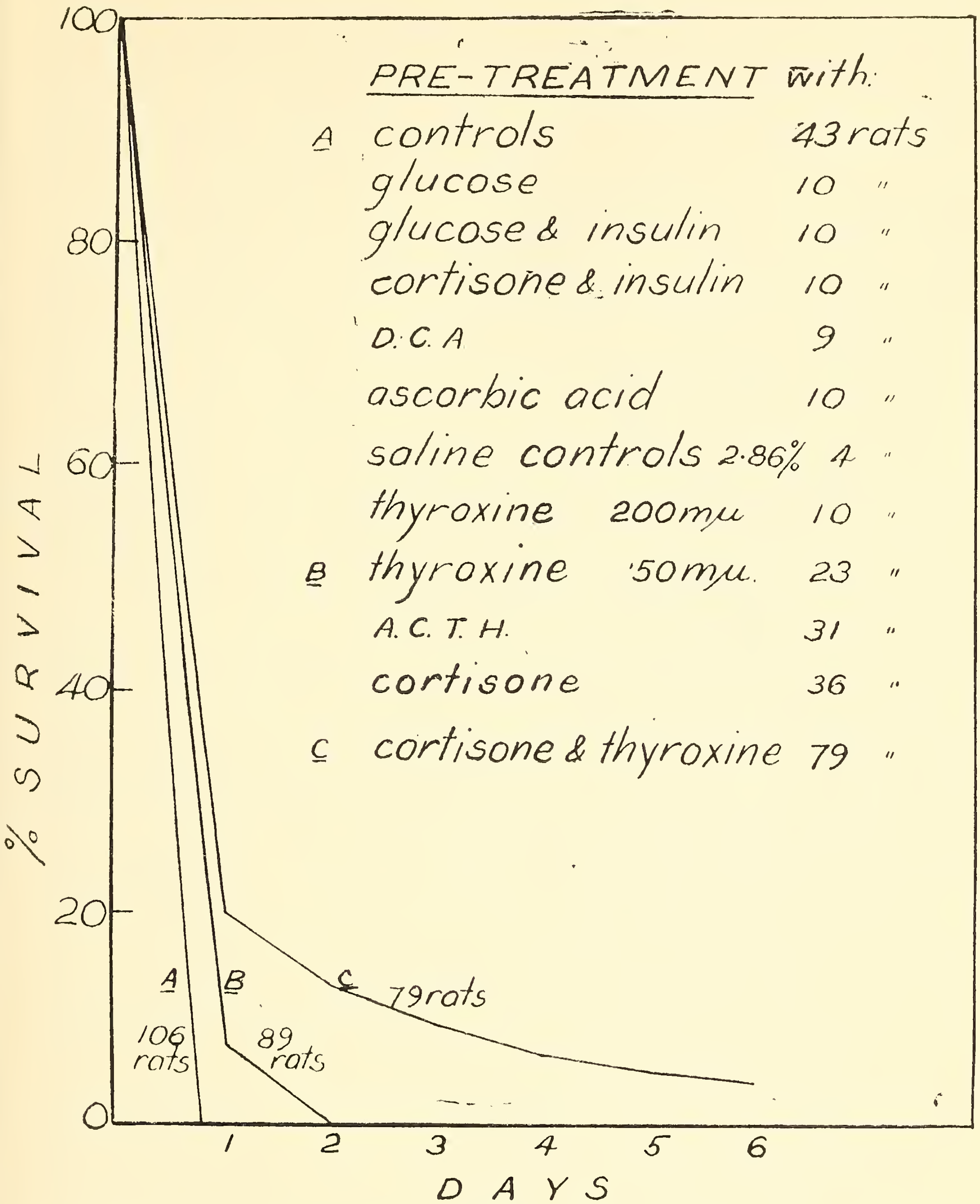

Fig. 5. Effect of various substances on the survival of clipped non-acclimatised rats exposed to cold.

Sayers (1950), whom I have quoted above, illustrates current conceptions of cortical behaviour by means of the accompanying diagrams (Figs. 6 and 7).

According to this concept then, the increased metabolism in response to exposure to cold may be initiated by impulses to the hypothalamus, but the metabolic response is sustained by increased output from the adrenal cortex. The stimulus to this is derived from the pituitary which may simply respond to diminished levels of cortical hormone in the venous blood.

I want to draw attention to one other consequence of the metabolic adaptation to cold, and that is the increased demand for vitamin C, ascorbic acid, under such conditions. Ascorbic acid is stored in the

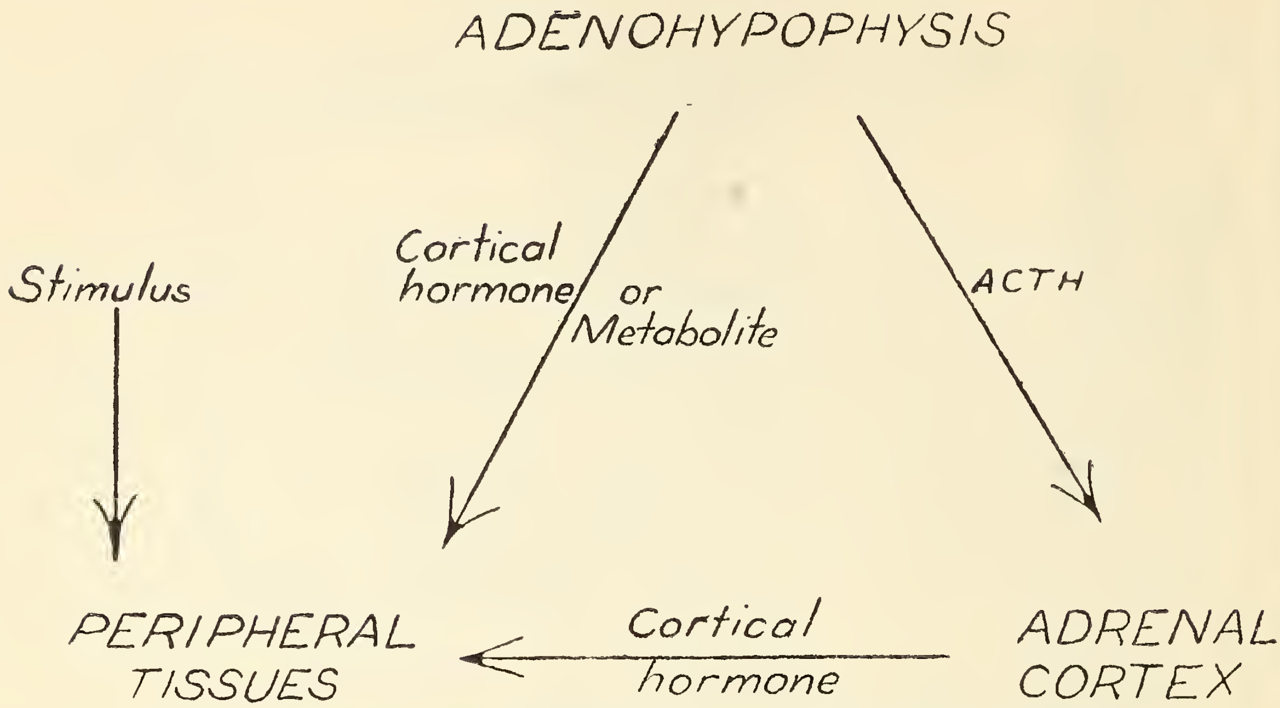

Fig. 6. Self-regularatory system (Peripheral—humoral concept).

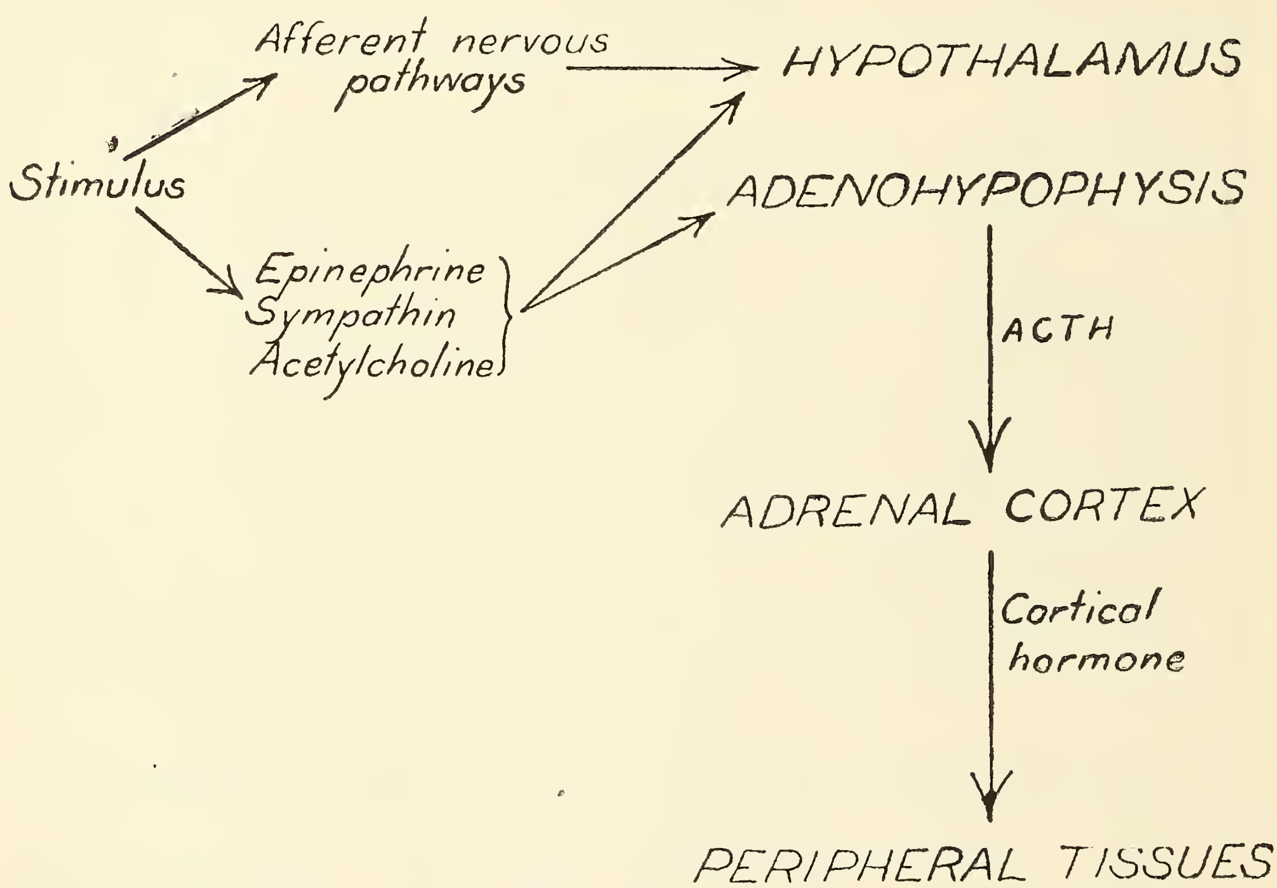

Fig. 7. Centrally driven system (Central—neural concept).

suprarenal and disappears when the suprarenal is stimulated by stress conditions. Dugal and Therien (1947) in an impressive series of experiments were able to show that ascorbic acid was necessary for resistance and adaption to cold by guinea pigs, animals which like man are unable to synthesise vitamin C. The resemblance between scurvy and certain features of adrenal insufficiency has been noted, but it seems certain that ascorbic acid is not concerned in the synthesis of adrenocortical hormones. It appears more likely that both cortical hormone and ascorbic acid are required to support cellular activity and that the demand for both is roughly parallel. Either may prove a limiting factor in cellular activity if the demand is great and the supply restricted. Classical scurvy, although probably a multiple deficiency, occurred most frequently in men performing strenuous muscular work in cold environments. Scurvy generally occurred among crews of sailing vessels after a strenuous rounding of Cape Horn, and it was the bugbear of polar explorers.

I have said that hormones, such as those of the adrenal cortex, and such substances as vitamin C, are necessary for the support of cellular activities. In spite of the fact that adrenalin has been known for close on fifty years, there is still no clear idea of its action and the same holds true for other hormones. Their general effect on metabolic processes has been explored extensively, but their connection with specific reactions occurring in cells remains obscure. With the vitamins however, which may be looked upon as exogenous hormones, there has been more success. The members of the vitamin B group have all been shown to be connected with specific stages of cellular metabolism and to be components of the catalysts accelerating cellular reactions, the enzymes. It is almost an article of faith with biochemists that both vitamins and hormones will ultimately be linked with the promotion of enzyme activity. Some recent publications support this view. Ascorbic acid, vitamin C, has been shown to be required for the oxidation of tyrosine in liver, a process which also requires the presence of α-keto-glutaric acid. Hormones have rarely been found to affect appropriate cell-free enzymes directly. Special importance therefore attaches to a recent paper by Knox (1951). Enzyme adaptation, that is, increased activity in a particular enzyme produced by treatment with the substrate of the enzyme and independent of the growth of selection of the cells, is well established for micro-organisms. Knox claims that the same phenomenon is demonstrable in liver with the enzyme tryptophane peroxidase and that it can be demonstrated both in slices and in cell-free preparations after treatment with the substrate tryptophane. He goes on to show that treatment of the animal with small doses of adrenalin or histamine will elicit a similar response which can be attributed to increased cortical hormone release. You and Sellers (1951) have also shown that after rats have been exposed to a cold environment for more than sixteen days, the oxygen consumption of liver slices, and the succinoxidase activity of liver homogenates is significantly increased. They point out therefore that increased activity of non-muscular tissues must contribute to the increased heat production brought on by exposure to cold.

I want now to turn to another factor which affects the production of heat by the animal, the influence of food. It has long been known that giving food to a fasting animal increases its heat production and that this effect varies with the kind of food given. This action of nutrients was called by Rubner the "specific dynamic action", and the additional heat produced by a given quantity of food became known as the heat increment. Lusk (1930) defined this action in the following way:—"If what we now call the basal metabolism of a typical animal be 100 calories per day and if 100 calories be administered to the animal in each of the several foodstuffs on different days, then the heat production of the animal after receiving meat protein will rise to about 130 calories, after glucose to about 106 calories, and after fat to about 104 calories". The large heat increment observed with protein feeding could also be observed with amino acids, and according to Grafe (1915), even with ammonium salts. Lusk goes on to say:—"Just as the source of muscular energy may be derived from the oxidation of fat in a fasting dog diabetic with phlorhizin, the source of energy for the specific dynamic action of protein is obtained from the oxidation of fat. It has been shown in numerous experiments that, after such a phlorizinised dog has received meat, the non-protein R.Q. is 0.70, or approximately that of fat''. Other experimenters found that the site of the extra heat production was in the liver and attempted to relate the extra heat production to the formation of urea.

However a case can be made out for the coupling of proteins with fat oxidation. It is well established that the initial stages of fat oxidation occur in the liver. By the process known as beta oxidation, the fatty acid is split into two carbon fragments (acetate) which unite to form acetoacetate. The nature of the two carbon fragment remains a mystery, but Weinhouse, Medes and Floyd (1946) have suggested that the combination of an acetyl group in an amide linkage is a normal step in acetate metabolism. This 'active acetate' may either condense with itself to form acetoacetate as occurs in the liver, or with oxal-acetate in the extra-hepatic tissues to form citric acid. The effect of protein feeding would then be to provide available amino groups in addition to the endogenous supply which would facilitate the formation of acetoacetate, the utilization of which in the extra-hepatic tissues, would in turn be dependent on metabolites derived either from carbohydrate or the glucogenic amino acids.

Be that as it may, Rubner quite clearly saw that the specific dynamic effect of exogenous protein could be used to replace that of endogenous protein in an animal exposed to cold. In other words the heat tax on the utilization of endogenous and exogenous protein is essentially the same. This idea has been very effectively used recently by Marston (1951).

The original concept of specific dynamic action was arrived at by feeding small amounts of food to fasting animals. It was later assumed that the same differential effects of protein, carbohydrate and fat would be manifest at all levels of nutrition and it has taken many years of patient experiment to show that this is not so. Under ordinary conditions of nutrition, at above maintenance levels, it is the metabolisable energy and not the protein content of the diet which dominates the production of heat (Forbes and others, 1944). In other words the relationship between intake of available energy and heat production is linear (Marston 1951).

I have perhaps spent rather too long in considering the sequence of events which follow the exposure of an animal to cold. Examination of the graph showing relationship between oxygen consumption and external temperature in the case of the rat shows an increase of heat production above as well as below the critical temperature. This is ascribed to the combined effects of muscular activity (panting, increased respiratory rate) and rise in body temperature which would tend to increase the rate of chemical reactions in the body. The animal may be able to establish thermal equilibrium between itself and its environment at a raised body temperature, or it may fail to do so and the body temperature will continue to increase until the upper limiting temperature is reached and the animal dies. Clearly the situation in these thermal environments calls for decreased heat production or increased heat dissipation or both. Here the sweating animals have a pronounced advantage and can tolerate environments which prove fatal to other animals.

Acclimatisation occurs, and in the sweating animal, the primary adaptive change is circulatory, blood is shunted to the outside and an increase of blood volume occurs. The non-sweating animals have less scope. Extra cooling is largely obtained by evaporation from the lungs, a process which varies in efficiency in different animals. Increased food consumption and increased activity both tend to move the animal farther from its position of equilibrium. The proverbial stillness of the Australian bush on a hot summer's day, ''where no birds sing'', is silent testimony to the precariousness of the position in which our fauna finds itself. Whilst our native animals can do as they please, our non-indigenous population, man and the domestic animals is expected to perform its allotted task, irrespective of the time of year. These activities involve consumption of food much above mere maintenance, and heat production is in general proportional to the intake of energy. The effects of high and low plane feeding on animals exposed to heat were clearly shown by Robinson and Lee (1947) in experiments conducted a few years ago. High rates of feeding resulted in increases of rectal temperature and respiratory rate in all the animals studied, and a reversal to a lower plane of nutrition quickly lowered these responses. A high protein diet had no significant effect on the reactions of animals to heat.

We have seen that adaptation to cold involves definite increases in endocrine activity essentially brought about by the increased metabolic activity. One might expect therefore that endocrine activity would diminish as environmental stimuli to metabolism decrease. There is some evidence that this is so. Seasonal changes have been observed in the weights of the adrenal and thyroid in animals, and in 17-ketosteroid excretion in man, which support the suggestion of diminished glandular activity in hot summer conditions and of an increase in winter. There is as yet no satisfactory method for the assessment of the level of adrenal activity in man. Urinary analyses involving the determination of 17-ketosteroids and of 'reducing steroids' obviously bear no necessary direct relation to adrenocortical activity and the analytical procedure for determining 'reducing steroids' is thoroughly unsatisfactory. The determination of protein-bound iodine and of iodine exchange in the thyroid offers hope of a more satisfactory measure of the activity of the thyroid.

If then we can regard raised body temperature as likely to be detrimental, we see that at the upper end of the critical zone, increased metabolism becomes increasingly difficult to tolerate, and the factors promoting increased metabolism, namely, increased food intake and endocrine activity, should also prove detrimental.

Food intake is largely determined by appetite and it appears that appetite is controlled by a nervous mechanism centred in the hypothalamus. Here also are located the temperature regulating centre. and the nervous mechanism for stimulating the pituitary. It is well established in humans that appetite declines as environmental temperatures rise. However, there is a limit to this form of control. Humans are able to dissipate the extra heat formed through increased food intake satisfactorily, but our domestic animals cannot do so effectively.

One would expect therefore that those functions which demand a rapid metabolic rate, such as milk and egg production, would tend to decline if the external conditions became increasingly less tolerable. This does in effect prove to be true. The problem therefore of producing such animals as high producing dairy cattle able to withstand severe tropical conditions is likely to prove difficult, more difficult than producing beef animals suited to the same conditions. In both cases it is likely that a compromise between what is considered desirable and what is practicable will have to be made. We have begun the study of some of these problems in Queensland, but more rapid progress demands far greater resources than we at present possess.

I want to conclude by putting in a plea for the greater recognition of the part that physiology and biochemistry have to play in the promotion of the welfare of our domestic animals. By historical chance, these studies have largely become linked with medical schools and applications to medicine form their primary reason for existence. Comparative physiology and biochemistry have much to offer, not only directly to the animal industries, but to our understanding of human physiology, so much of which has been founded on experimental work, not with vitamins, but with such humble animals as rats and guinea pigs.

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VOLCANIC ROCKS OF AITAPE, NEW GUINEA.

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(With 10 Text-figures.)

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ABSTRACT.

Volcanic rocks at Aitape, Eastern New Guinea are Lower Miocene andesitic agglomerates with occasional andesitic lavas and limited areas of basalt. The basalts verge on basic andesite; they are partly submarine flows and in places are soda-rich. The Aitape volcanic suite belongs to the earliest period of formation of the Bismarck Archipelago Inner Volcanic Arc of Neogenic to Quaternary age and is situated at the north-western end of this arc. The volcanic rocks are members of the extensive andesite-basalt group of lavas and ejectamenta that encircles the Pacific Basin. The basaltic rocks reveal some similarities and certain marked differences compared with Central Pacific (Hawaiian) basalts, but the suite is characteristically allied to the Circum-Pacific volcanic rocks. Both basaltic and andesitic rocks in the Aitape volcanic suite have been subjected in parts to strong deuteric alteration and solfataric action.

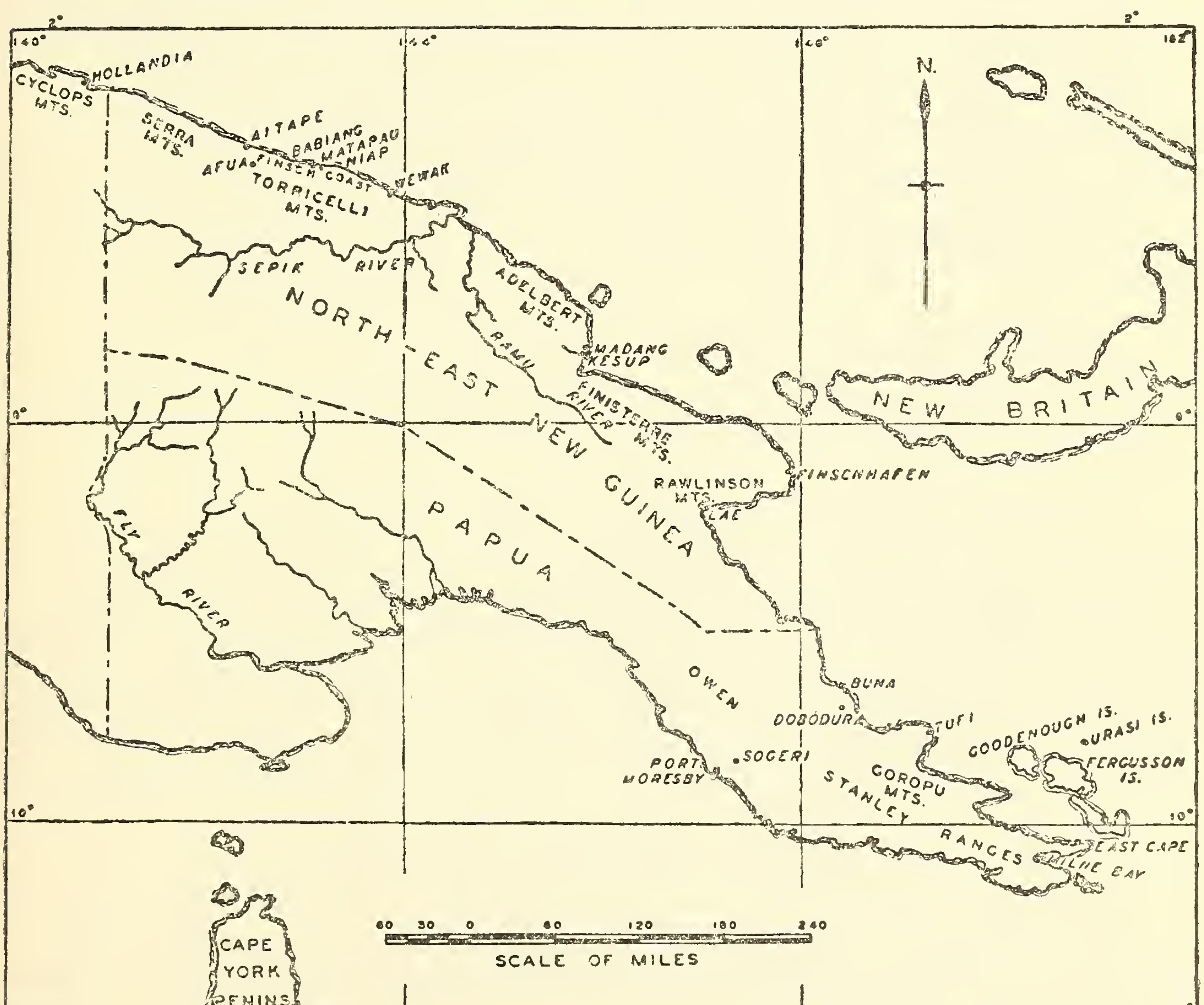

Figure 1.—Locality Map of South-eastern New Guinea. (Based on War Office Map 1: 4,000,000 of East Indies, Sheet 2, 1928.)

C

INTRODUCTION.

The paper deals with the petrology of a collection of Aitape volcanic rocks made in 1944 by A. Coulson, M.Sc., who also supplied field notes and specimens of other New Guinea volcanic rocks.

Aitape is situated in the Bewani-Pual Depression north of the Torricelli Mountains on the north-western coast of Eastern New Guinea (figure 1).

The Lower Miocene volcanic rocks of Aitape occur near the north-western extremity of the Neogenic-Quaternary Inner Volcanic Arc of the Bismarck Archipelago (Van Bemmelen, 1939). This arc, in part still active, though not in the Aitape district itself, extends from the vicinity of the 143rd meridian, south-easterly through a string of Recent volcanic islands—Kairiru to the Schouten Islands on to Manam Island, Karkar, Bagabag, Long and Umboi Islands to New Britain, where it follows the north coast to the 152nd meridian near Rabaul (figure 2).

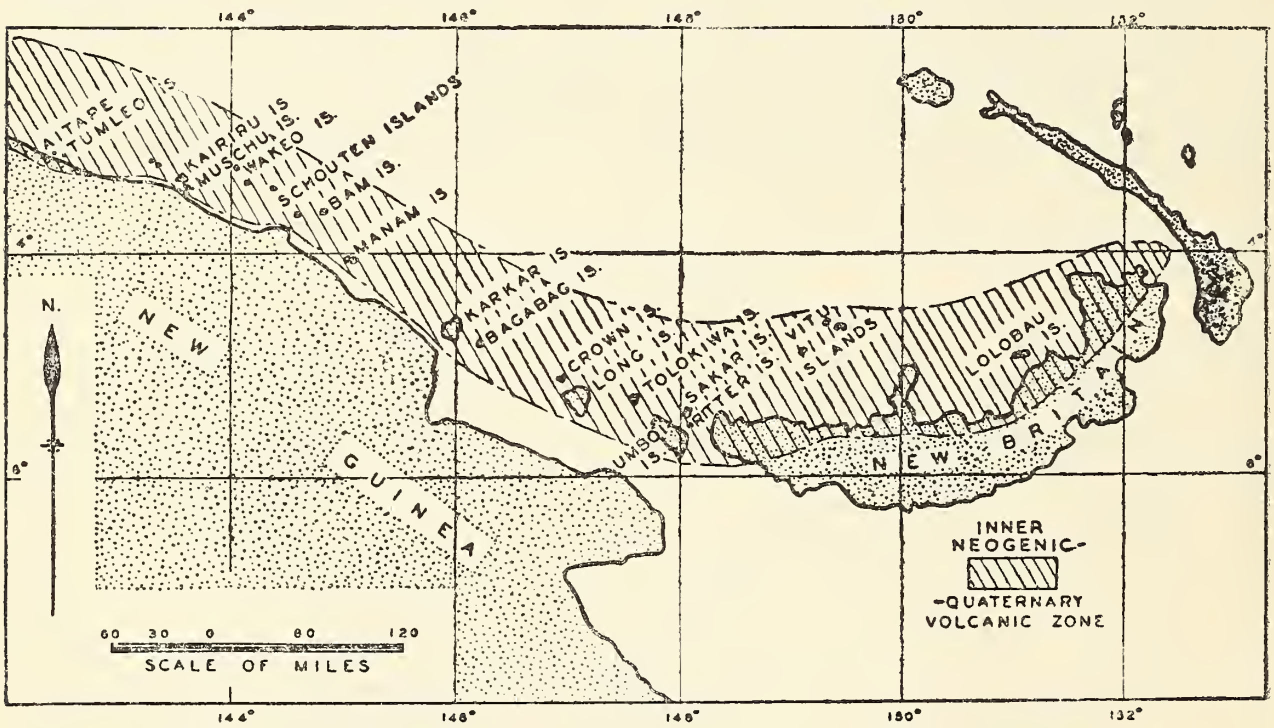

Figure 2.—Sketch Map showing the Inner Volcanic Arc of the Bismarck Archipelago.

The arc was a zone of strong volcanic activity in Lower Miocene times and again from (?)Pleistocene to present times. The more recently active part of the arc is composed of a series of lines of eruption arranged more or less *en échelon*, the products of volcanicity being built up on the summits of submarine ridges. The volcanic rocks of the arc are intermediate to basic lavas and ejectamenta emitted from active, dormant and extinct (Early Quaternary and Lower Miocene) volcanoes. The Aitape volcanic series is exclusively Lower Miocene.

GEOLOGY OF THE DISTRICT.

The general geology of the Aitape district is indicated in figure 3.

In the vicinity of the coast, the area is covered largely by Coastal Plain alluvium, up to 10 miles wide and recently uplifted a few feet. Recent coral limestones cover three to four square miles of the country west of the Raihu River mouth, near Aitape. Aerial photographs reveal a series of low, longitudinal sand ridges east and west of the Raihu River mouth and northwest of Tepier Plantation (figure 4).

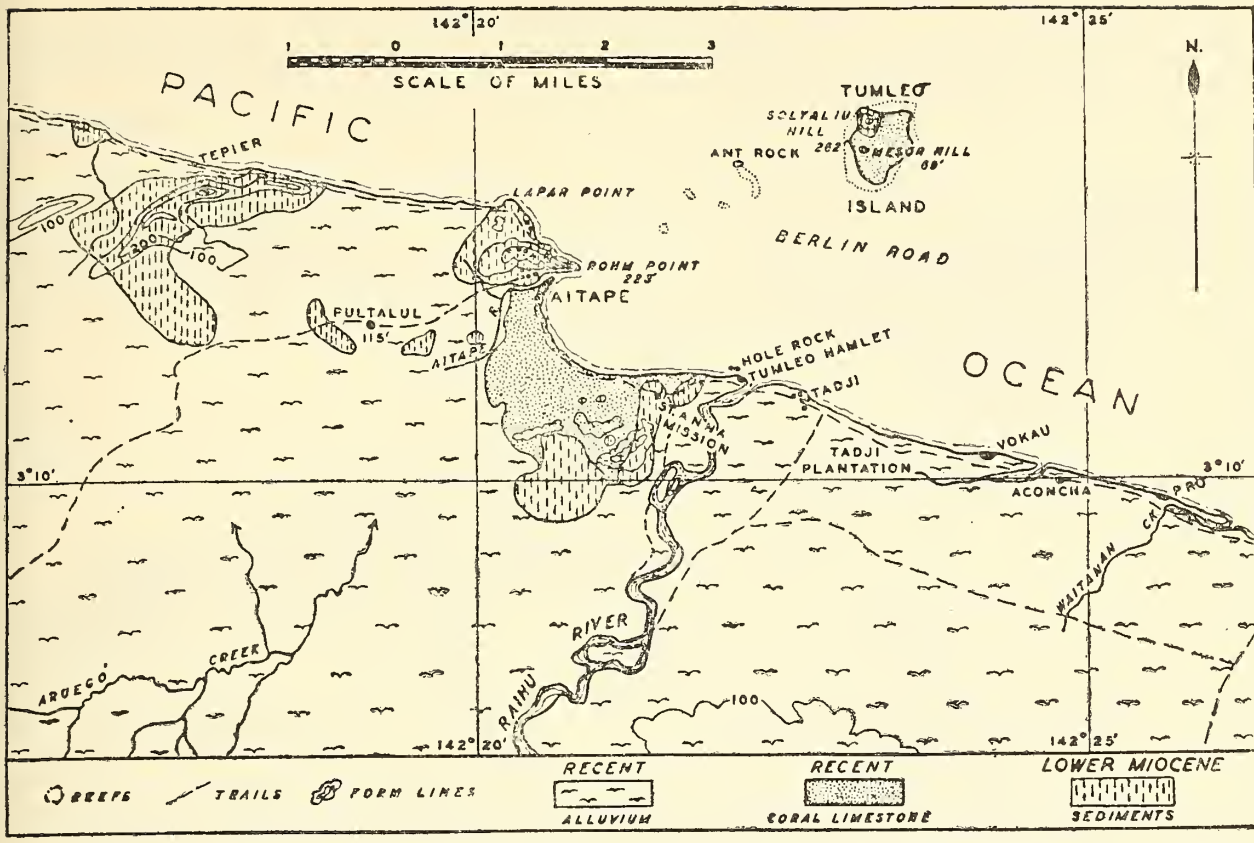

Figure 3.—General geological Map of the Aitape District. Based on U.S. Army Map of Aitape East, A54/15, N.E. New Guinea Provisional Map (1 inch = 1 mile). Preliminary Sheet, 1943. Geology based on Anglo-Persian Oil Co. Ltd. Geological Survey (see Nason Jones, 1920-1929.)

The oldest rocks exposed in the neighbourhood of Aitape, are interbedded Lower Miocene sediments (figure 3) and volcanic rocks, but in the eastern part of the Torricelli Mountains, behind the coastal plain, remnant patches of Eocene limestones and shales were recorded by Nason Jones (1920-1929). The Lower Miocene sediments outcrop near Aitape in the following areas—

(i) in Tepier Plantation, south of Tepier,

(ii) east and west of Pultalul Hill,

(iii) between Lapar Point and Rohm Point north of the Aitape River,

(iv) in the St. Anna Mission area west of the Raihu River,

(v) in the west centre of Tumleo Island.

Tumleo Island (figure 5) is principally Recent coral limestone and sand on the low-lying regions, above which rise two prominent hills. The lower, Mesor Hill (69′) in the west centre, is composed of Lower Miocene limestone containing *Spiroclypeus* and other Orbitoids. The higher, Solyaliu Hill (262′) in the northwest, is composed of volcanic agglomerate.

The areal distribution of the Neogene volcanic rocks, which in parts overlie and in parts are interbedded with the Lower Miocene sediments, is indicated in figure 4.

Two outcrops in Tepier Plantation, 4 miles west of Aitape, form the largest single outcrops of the Aitape volcanic suite. Smaller outcrops occur near and at Rohm Point and Lapar Point (=Cape Roon of Richarz, 1910), near Aitape, at Solyaliu Hill on Tumleo Island $3\frac{1}{2}$ miles east-north-east of Aitape, at St. Anna Plantation 2 miles east-south-east of Aitape, and the smallest outcrop forms a low hill, Pultalul Hill

(115′) 1½ miles west-south-west of Aitape. These outcrops form lava residuals and hills of agglomerate rising up to a maximum of 488′ above the Aitape Coastal Plain.

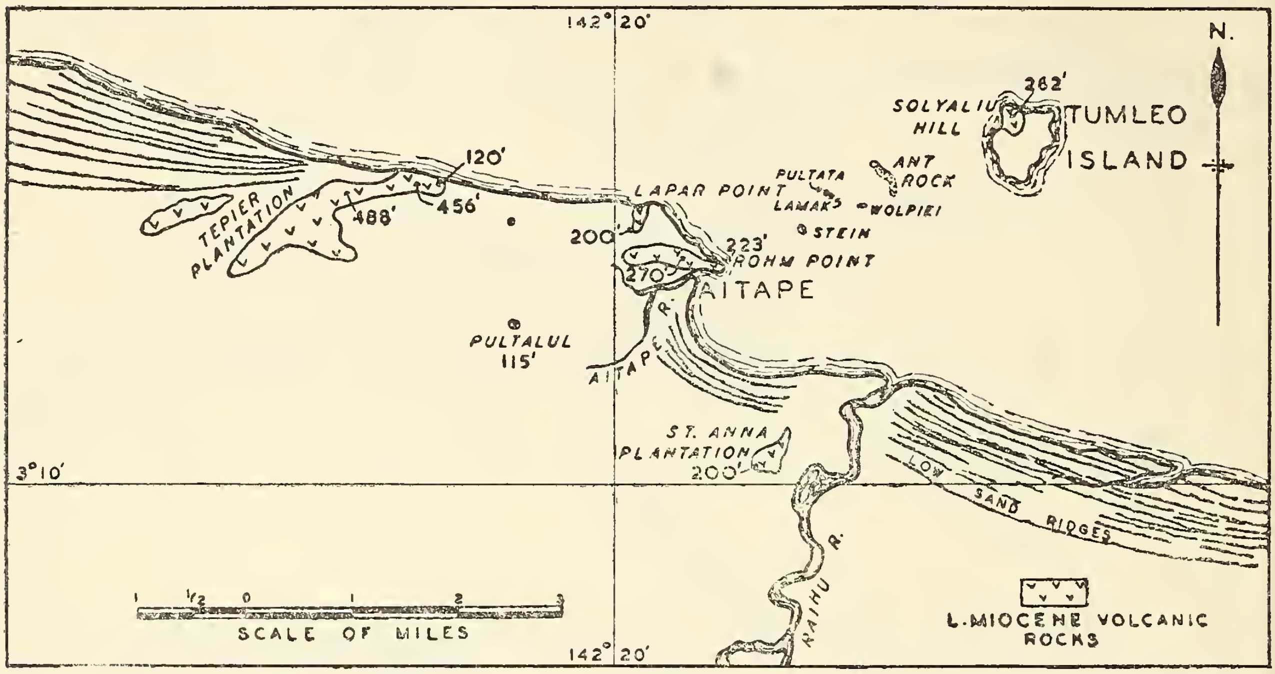

Figure 4.—Sketch Map showing outcrops of Neogene Volcanic Rocks and heights from which some of the specimens were obtained in the Aitape District.

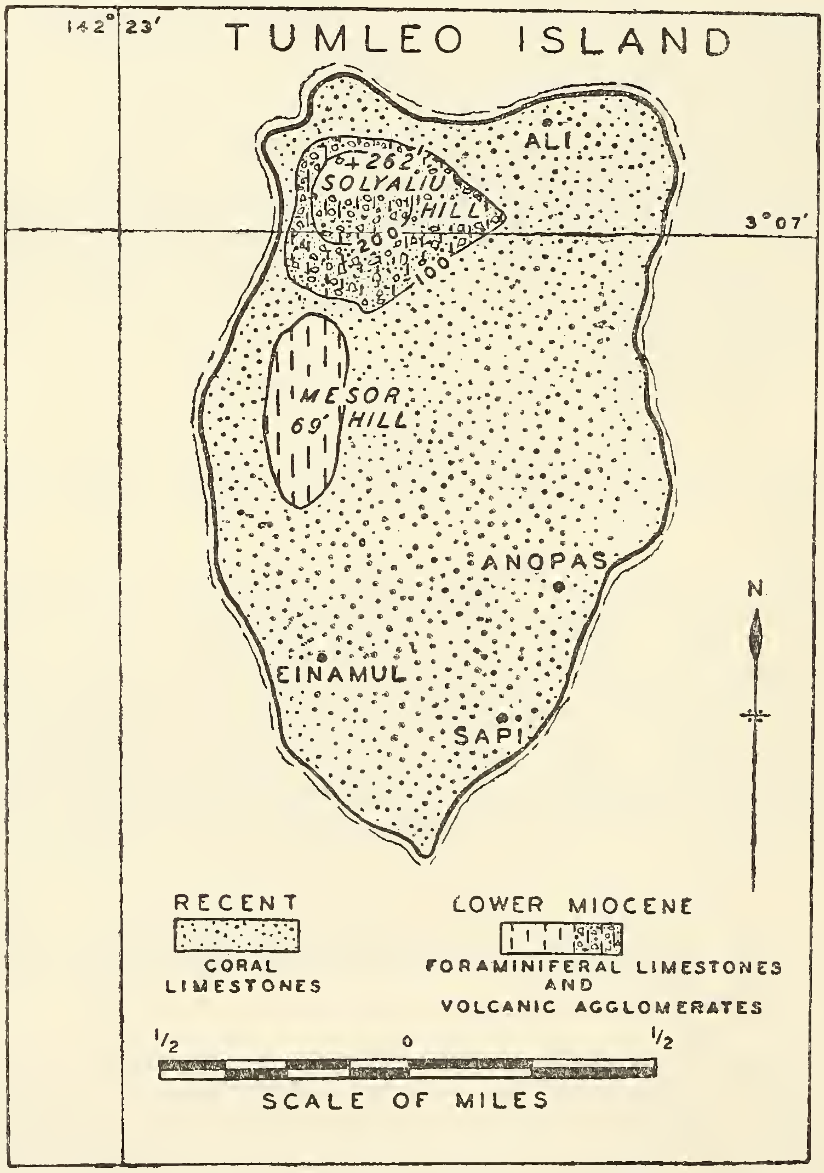

Figure 5.—Geological Map of Tumleo Island. Based on U.S. Army Map of Aitape East, N.E. New Guinea, A54/15, Provisional Map (1 inch = 1 mile). Preliminary Sheet, 1943. Geology based on Anglo-Persian Oil Co. Ltd. Geological Survey (see Nason Jones, 1920-1929).

A string of small reefs—Ant Rock, Pultata Reef, Lamak Reef and Stein Reef (figure 4)—extending between Tumleo Island and Rohm Point, consists of volcanic rocks similar to those around Aitape on the mainland.

The only distinct evidence of a centre of eruption occurs in the northwest of Tumleo Island, where a volcanic neck of porphyritic andesite cuts through the agglomerate (figure 6) comprising Solyaliu Hill (figure 5).

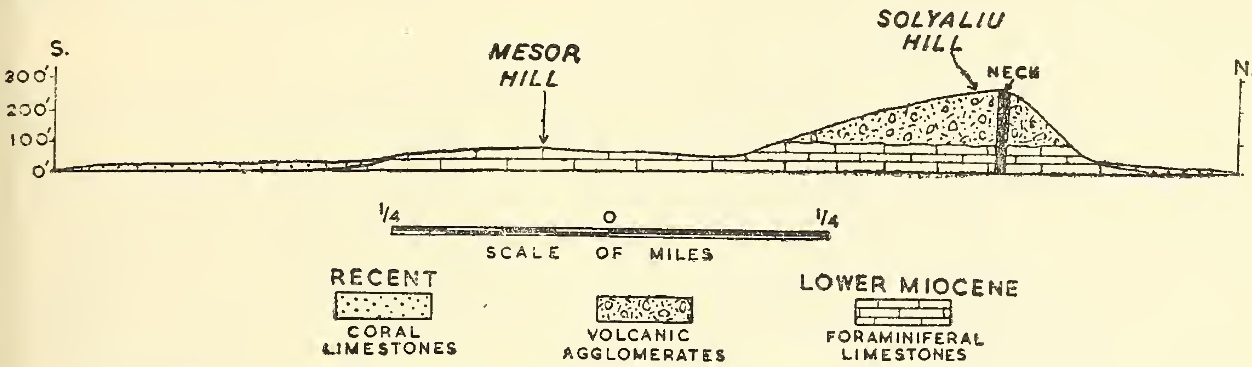

Figure 6.—Geological Sketch Section from south to north through the western portion of Tumleo Island.

DISTRIBUTION OF THE VOLCANIC ROCKS.

The various rock types comprising the Aitape volcanic suite occur in the following localities:

Tepier Plantation. Andesitic agglomerates extend up to 200′ above sea level in the western outcrop of the Tepier area. The easterly outcrop is composed essentially of two hills, the higher (488′) in the south-west and the lower (456′) near the coast in the north-eastern portion of the outcrop. In the north-eastern portion, hill 456′ consists principally of amygdaloidal porphyritic augite andesite, with occasional representatives of hornblende-augite andesite and pyribole andesite (i.e. with hypersthene, augite and hornblende). The rocks are largely heavy agglomerates, in parts forming old sea cliffs up to 120′ high (now 5 to 8 chains in inland) and are flanked on the north by old beach sand-ridges. At Tepier Hill (488′) in the south-western portion of the eastern outcrop, the andesitic rocks (up to 400′ thick), are the thickest known volcanic exposures in the Aitape district.

Some of the Tepier andesites resemble andesite fragments in the Tumleo Island agglomerate. Sub-columnar structures occur in andesite lavas exposed on a cutting face along the road descending west to Tepier Plantation. There is a notable absence of tuff and scoria from the volcanic rocks throughout the Tepier-Lapar Point area.

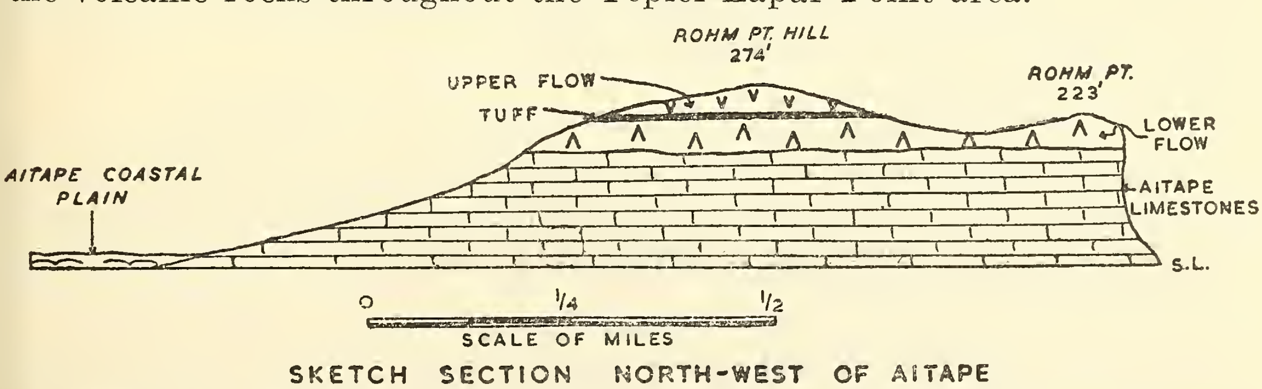

Figure 7.—Geological Sketch Section through Rohm Point, showing relationship of the two lava flows and the tuff bed to Tertiary (Lower Miocene) sediments. Section drawn along strike of beds dipping 20° to 25° to the south.

Lapar Point. Amygdaloidal basalt at Lapar Point, ¾ of a mile north-west of Aitape Settlement, forms a steep coastal cliff up to 200′ high. Volcanic breccia has been described from this cliff by Richarz (1910, p. 436).

Rohm Point. Two flows of basalt, separated by a bed of tuff, are exposed on top of Tertiary limestone at Rohm Point (figure 7). The rocks here form hills 223′ above sea level at the coast and 274′ high a short distance to the west. The lower flow is approximately 30′ thick, the tuff 10′, the upper flow varies from 40′ to 50′ thick and has been considerably eroded.

The Rohm Point upper flow, sampled from above the tuff bed at a height of 270′ above sea level at Rohm Point Hill, and the lower flow, sampled from below the tuff bed at 200′ in the same locality, consist of a similar amygdaloidal basalt. Lava from 223′ at Rohm Point proper, is a more crystalline phase of the lower flow. Portions of the Rohm Point flow appear as pillow lavas and contain Tertiary globigerina limestone included between the blocks as a cement (Nason Jones, 1920-1929, vol. III, p. 55, fig. 8). In view of this, and the presence of a chilled phase of the basalt here, it is evident that portions of the volcanic rocks are submarine flows.

Pultalul Hill. Approximately 50′ of basalt capping Tertiary limestone, forms Pultalul Hill (115′) near the native village of Pultalul. Rising from the Aitape Coastal Plain, the hill is more or less surrounded by swampy country.

St. Anna Plantation. An amygdaloidal, soda-rich, glassy basalt, similar in many ways to the Lapar Point flow, is occasionally associated with tuffs and limestone, half a mile south of the St. Anna Mission Station, south-east of Aitape.

Solyaliu Hill, Tumleo Island. Andesitic agglomerates cut by a volcanic neck of porphyritic augite-hypersthene andesite carrying abundant phenocrysts of augite up to 10 mm. across, comprise Solyaliu Hill (figures 5 and 6).

Richarz (1910, p. 419) described these rocks as volcanic andesitic breccia. Little scoriaceous rock is present, and the exposure consists largely of angular blocks of lava up to 5′ across, set in a grey, tuffaceous matrix. Constituents of the agglomerate are red, limonitized porphyritic augite andesite and occasional blocks of hard, dense, grey porphyritic hornblende-augite andesite, augite andesite and porphyritic augite-hypersthene andesite. In addition are a few ejected fragments of gabbroic rocks derived from the basement complex rocks in the Torricelli Mountains region, and rare fragments of Tertiary limestone. Richarz (1910, p. 434) also recorded hornfels and hornblende gabbro among the ejected blocks.

AGE RELATIONS OF THE VOLCANIC ROCKS.

The volcanic rocks on Tumleo Island and the mainland nearby, are grouped (figure 5) with the Lower Miocene limestones and tuffaceous limestones in age, according to the Anglo-Persian Oil Co. Ltd. geological survey (see Nason Jones, 1920-1929). The presence of ejected blocks of Miocene limestone in the agglomerate at Solyaliu Hill, suggests a post-Miocene age for the volcanic rocks, but they are fundamentally the same age as the mainland volcanic rocks that are in part interbedded with Lower Miocene limestones and tuffaceous limestones and were formed penecontemporaneously with them.

There is no evidence to indicate any real difference in age between the basaltic and andesitic rocks in the Aitape volcanic suite. Nowhere have they been observed in contact, but they are closely associated in space. The basaltic rocks at Rohm Point and St. Anna Plantation were evidently poured out before the andesites, because:

(i) they have been rather more strongly eroded,

(ii) they are associated with Tertiary limestones and appear as dissected remnants of flows, while the andesites have not been observed in contact with the limestones and are built up to greater heights than the basalts,

(iii) the andesitic rocks are somewhat fresher in appearance and little eroded.

The more basic flows are regarded as the earliest products of Neogene volcanism in the Aitape district. They broke through a sea floor composed of Tertiary deposits including limestones, thus accounting for (*a*) the chilled character of parts of the flows, (*b*) the pillow structures and (*c*) Miocene globigerina limestone cementing the pillow structures.

Richarz (1910, p. 449) suggested from microscope investigations that hornblende andesite and hornblende gabbro, found as ejected blocks in the agglomerate on Tumleo Island, represented the porphyritic and granular facies respectively of the same magma. Chemical analysis, however, (table II, columns 11 and 12) does not confirm this, and according to the field evidence, they cannot be of the same age and derived from the same magma. The andesitic rocks are Lower Miocene, the complex basement rocks exposed in the Torricelli Mountains (figure 10), of which similar gabbroic rocks form a part, are pre-Eocene and possibly of considerable antiquity.

TABULAR REPRESENTATION OF THE DISTRIBUTION OF VOLCANIC ROCKS IN THE AITAPE DISTRICT.

The various petrological types, the localities at which they occur, their frequency of occurrence and nature in the field are indicated in table I. The volcanic rocks set out in this table have characteristic merocrystalline textures and contain both fine-grained and porphyritic examples. The normal type augite andesites, the porphyritic augite andesites and the amygdaloidal porphyritic augite andesites are more common than hornblende andesites and pyribole andesites wherever andesites are represented in the Aitape district, i.e. on Tumleo Island and in the Tepier Plantation area.

TABLE I.

Rock Type.	Locality.	Frequency at Each Locality.	Nature in Field.
Basaltic Rocks—			
Amygdaloidal Basalt ..	200′ above s.l., Rohm Pt. Hill (Lower Flow)	Principal type	Flow
Basalt	223′ above s.l., Rohm Pt. proper	Principal type	Flow
Amygdaloidal Basalt ..	270′ above s.l., Rohm Pt. Hill (Upper Flow)	Principal type	Flow
Amygdaloidal Basalt ..	St. Anna Plantation ..	Principal type	Flow
Amygdaloidal Basalt ..	200′ cliff, Lapar Pt. Hill	Principal type	Flow
Basalt	Pultalul Hill (115′) ..	Principal type	Flow

TABLE I.—*continued.*

Rock Type.	Locality.	Frequency at Each Locality.	Nature in Field.
ANDESITIC ROCKS—			
Augite Andesite ..	Solyaliu Hill, Tumleo Island	Occasional ..	Agglomerate
Porphyritic Augite Andesite	Solyaliu Hill, Tumleo Island	Occasional ..	Agglomerate
Amygdaloidal Porphyritic Augite Andesite	Tepier East Hill (488′)	Common ..	Agglomerate
Hornblende-Augite Andesite	Tepier East Hill (456′)	Occasional ..	Agglomerate
Porphyritic Hornblende-Augite Andesite	Solyaliu Hill, Tumleo Island	Common ..	Agglomerate
Porphyritic Augite-Hypersthene Andesite	Solyaliu Hill, Tumleo Island	Occasional ..	Volcanic Neck
Pyribole Andesite ..	Tepier Plantation ..	Uncommon ..	Agglomerate
EJECTED BLOCKS—			
Gabbroic Rocks ..	Solyaliu Hill, Tumleo Island	Occasional ..	Fragments up to 6″ across
Hornfels	Solyaliu Hill, Tumleo Island	Occasional ..	
Tertiary Limestone ..	Solyaliu Hill, Tumleo Island	Occasional ..	

PETROGRAPHY.

BASALTIC ROCKS.

The Aitape basalts are mafelsic and distinct from the andesites in many respects, although in parts they tend to verge on basic andesites. They contain altered olivine, more prominently developed amygdaloidal structures, abundant iron ore minerals and are in parts soda-rich, with hypersthene typically absent. They do not show the porphyritic textures characteristic of the andesites. The few microphenocrysts of plagioclase, more basic than those in the andesites, show little zoning, thus contrasting sharply with the numerous zoned-twinned microphenocrysts and laths of plagioclase in the andesites. Both basaltic and andesitic rocks contain members with glassy groundmasses. The basaltic rocks are limited in both lateral and vertical directions in the neighbourhood of Aitape.

ST. ANNA PLANTATION BASALT. The St. Anna Plantation amygdaloidal basalt has a glassy base with fine-grained groundmass constituents. Minute, but abundant grains, skeletal crystals and cubes of magnetite are prominent. Small, needle-like, unaltered plagioclase felspars show marked fluidal alignment in parts (figure 8). The dominant felspar is albite-oligoclase, with some microphenocrysts of albite. Occasional microphenocrysts of unaltered augite have a pale yellow colour as in all the basalts and most andesites of the Aitape volcanic suite. The unaltered character of the augite is a marked feature of the Aitape volcanic rocks, especially in parts of the flows where the felspars have been albitized. Benson (1915) and Scott (1950) have also noted a similar feature in basaltic rocks from New South Wales and King Island, Tasmania.

All the olivine crystals are typically altered to serpentinous products, opal with chlorite, calcite and secondary iron hydroxide. These secondary products also form irregular patches in the groundmass.

The augite has only been partially replaced in some parts of the rock by pleochroic delessite, which forms occasional cores in a few of the augite crystals.

A striking feature of the rock is the large number of infilled vesicles, producing the well-developed amygdaloidal structure. The largest amygdales seldom exceed 4 mm. in length but are often complex in character (figure 8). Most of the amygdales are subspherical or ovoid, but a few are irregularly elongated (figure 8).

Figure 8.—Sketch of microstructures in amygdaloidal basalt, St. Anna Plantation, Aitape. (x20). Showing amygdales lined with opal-bearing chlorite (unstippled) and infilled with concentric and radial growths of calcite and large calcite crystals. Phenocrysts of olivine (at bottom of sketch) altered to calcite and opal-bearing chlorite pseudomorphs. Augite phenocrysts (one at top of sketch) fresh. Glassy groundmass with partial fluidal alignment of albite-oligoclase laths and abundant grains and cubes of magnetite.

The larger amygdales are lined with narrow zones of pale greenish opaline silica containing chlorite. Smaller amygdales are often completely infilled with similar material. In many amygdales, similar lining material encloses spherulitic calcite. Amygdales infilled by greenish opal with chlorite, sometimes contain patches of clear opal, sometimes one crystal only of a zeolite having the properties of chabazite.

Rohm Point Hill Upper Flow. Amygdaloidal basalt sampled at 270′ on Rohm Point Hill, occurs above the tuff band (see figure 7). The amygdales, filled with brownish to colourless opaline silica and chloritic matter, are smaller than at St. Anna Plantation, but larger than in the lower flow at Rohm Point Hill. The rock has a coarser-grained texture than the flow sampled from 223′ at Rohm Point proper and from 200′ at Rohm Point Hill. Labradorite laths and pale yellowish augite crystals are larger and there are more and larger pseudomorphs after olivine.

The groundmass of the rock consists of a pale brown to colourless, interstitial glass, crowded with magnetite grains.

Rohm Point Hill Lower Flow. In the lower flow at Rohm Point Hill, small plagioclase laths have been completely altered to micro- and crypto-crystalline aggregates. Olivine is altered to serpentinous products and opaline silica. Unaltered, pale yellow augite crystals are numerous in a groundmass composed of brown to almost black glass. Many small amygdales are lined with radial and concentric growths of pale green, crypto-crystalline silica, sometimes containing one narrow shell of quartz. Colourless opaline silica infills a few amygdales and forms small veinlets in parts of the groundmass.

Rohm Point Lower Flow and Pultalul Flow. The Rohm Point lower flow, sampled from approximately the same height (223′) as the lower flow with which it is presumably contiguous at Rohm Point (sampled at 200′), shows marked differences from the Rohm Point outcrop. In thin section it resembles the basalt at Pultalul Hill, although it is slightly different in chemical composition (cf. columns 3 and 4 in table II).

The main differences from the Rohm Point Hill lower flow are (*a*) the rock is more crystalline, containing more and larger crystals, particularly of augite, and rather less glass which is darker brown, interstitial and contains fewer minute magnetite grains, (*b*) the felspars are fresher and (*c*) although vesicular, few of the vesicles are infilled with secondary mineral matter.

The felspar laths are basic labradorite. Abundant pale yellow augite crystals are identical with augite in other Aitape basalts. Olivine pseudomorphs are few in number and consist largely of serpentinous products. Pale brown and colourless opaline silica infills a few vesicles and forms narrow fringes to others.

Lapar Point Flow. The amygdaloidal rock forming sea cliffs 200′ high at Lapar Point, is intermediate between basalt and andesite. It is a finer-grained phase of the Aitape basaltic rocks, having smaller plagioclase laths and augite crystals and rather more dark groundmass glass. Groundmass plagioclase laths show pronounced streaming and consist of albite-oligoclase, as in the St. Anna Plantation flow. Quartz occurs in both calcite-infilled and chlorite-infilled vesicles. The presence of albite in the groundmass was originally noted by Richarz (1910, p. 436).

The abundance of secondary minerals replacing some of the ferro-magnesian minerals, particularly olivine, and the replacement of parts of the groundmass by similar materials and by albite, suggest a spilitic character, although chemical analysis (table II. column 2) does not reveal any marked excess of soda at Lapar Point compared with the St. Anna Plantation rock.

CHEMICAL COMPOSITION OF THE BASALTIC ROCKS.

Analyses of the Aitape basalts are compared with analyses of average basalts, average spilites, Central Pacific (Hawaiian) and selected Circum-Pacific basalts in table II. Two previously recorded analyses of gabbro (Richarz, 1910) from Tumleo Island are also included for contrast with the basalts (and the andesites) of the Aitape district.

TABLE II.

—	1	2	3	4	5	6	7	8
SiO_2 ..	50·12	50·86	50·45	49·68	51·22	46·05	46·01	49·6
Al_2O_3 ..	14·98	17·02	17·46	15·89	13·66	14·83	15·21	16·3
Fe_2O_3 ..	4·08	4·82	5·25	4·88	2·84	2·80	1·35	2·8
FeO ..	2·52	1·89	2·24	2·73	9·20	7·44	8·69	8·2
CaO ..	9·06	7·36	8·77	10·58	6·89	10·04	8·64	8·8
MgO ..	9·11	7·27	5·48	6·34	4·55	4·85	4·18	5·0
K_2O ..	1·61	1·65	1·74	0·71	0·75	0·38	0·34	0·8
Na_2O ..	4·07	3·13	3·40	2·33	4·93	4·31	4·97	4·8
TiO_2 ..	0·90	0·47	0·77	0·90	3·32	2·50	2·21	0·6
MnO ..	0·24	0·24	0·24	0·26	0·25	0·31	0·33	0·2
P_2O_5 ..	0·27	0·54	0·24	0·20	0·29	0·38	0·61	0·1
H_2O (+)	1·82	2·90	2·04	3·50	1·88	3·04	2·48	2·6
H_2O (−)	1·19	1·89	1·90	2·02		0·30	..	0·2
Cl ..	0·01	0·01	nil.	nil.	..	..	..	..
CO_2 ..	0·25	0·30	0·03	0·05	0·94	4·09	4·98	0·1
Total ..	100·23	100·44	100·01	100·07	..	..	..	..
Sp. Gr.	2·59	2·58	2·67	2·71	..	..	..	..

(The specific gravity values were determined in distilled water at 24·5°C.)

—	9	10	11	12	13	14	15
SiO_2	49·06	50·44	47·97	46·09	49·25	52·63	51·98
Al_2O_3	15·70	14·00	20·03	12·76	16·31	17·62	17·20
Fe_2O_3	5·38	3·15	8·08	2·65	6·47	6·49	8·22
FeO	6·37	8·27	1·29	4·50	3·13	3·10	2·00
CaO	8·95	10·19	12·10	16·65	10·58	8·62	8·17
MgO	6·17	6·73	5·43	14·42	6·16	5·64	5·41
K_2O	1·52	0·48	0·17	..	0·05	1·73	0·90
Na_2O	3·11	2·58	1·54	0·60	2·22	3·38	3·84
TiO_2	1·36	3·06	1·46	0·45	2·03	0·07	0·36
MnO	0·31	0·12	tr.	..	tr.	tr.	..
P_2O_5	0·45	0·29	v.sl.tr.	..	0·10	0·47	0·99
H_2O (+) ..	1·62	..	2·04	2·43	3·14	0·79	0·62
H_2O (−) ..	..	..			..	..	..
Cl	..	..	..	..	..	..	..
CO_2	..	..	..	..	..	..	..
Total	..	..	100·11	100·55	99·48	100·54	99·69
Sp. Gr.	..	..	..	..	..	..	2·72

KEY TO TABLE II.

1.—Amygdaloidal basalt, hill 200′, St. Anna Plantation, Aitape (anal. G. C. Carlos).

2.—Amygdaloidal basalt, 200′ cliff, Lapar Point Hill, Aitape (anal. G. C. Carlos).

3.—Basalt, Pultalul Hill (115′), Aitape (anal. G. C. Carlos).

4.—Basalt, Rohm Point proper, 223′ above sea level, Aitape (anal. G. C. Carlos).

5.—Average spilite according to N. Sundius ("On the Spilitic Rocks", *Geol. Mag.*, 67, (1930), pp. 1-17).

KEY TO TABLE II.—*continued.*

6.—Average of seven spilites from various localities set out in Washington's Tables (H. S. Washington, (1917-1918), Professional Paper No. 99, *U.S.A. Geol. Survey*).

7.—Average spilite according to A. K. Wells ("The Nomenclature of the Spilitic Suite", Part II, *Geol. Mag.*, lx (1923), p. 62).

8.—Average of four King Island (Tasmania) spilites, analysed by Miss B. Scott (1950).

9.—Average basalt according to A. K. Wells (loc. cit.).

10.—Average of twenty-nine Hawaiian basalts (G. A. Macdonald—"Hawaiian Petrographic Province", *Bull. Geol. Soc. America*, vol. 60 (1949), pp. 1541-1596).

11.—Hornblende gabbro (inclusion in hornblende andesite), Tumleo Island, Aitape (anal. E. Ludwig—see Richarz, 1910).

12.—Olivine gabbro (waterworn, found on Tumleo Island and of the same nature as the olivine gabbro so common in the Torricelli Mountains nearby), (anal. E. Ludwig—see Richarz, 1910).

13.—Basalt, Retschnaia Bay, Copper Island, Commander Islands, Bering Sea (anal. W. Staronka—see J. Morozewicz, *Mem Comm. G. Russ.*, No. 72 (1912), p. 72).

14. Basalt, Burney Butte, Shasta County, California (anal. R. B. Riggs—see J. S. Diller, *U.S. Geol. Surv. Bull.*, 148 (1887), p. 200).

15. Basalt, Cerro de Guadalupi, Puebla, Mexico (anal. A. Rohrig—see A. Hoope in Felix and Lenk, *Petr. G. Mex.* II (1899), p. 211).

Compared with the analyses of the Aitape andesites (see table III, columns 1 and 2), the analyses of the Aitape amygdaloidal basalts (table II, columns 1 and 2) are distinctly lower in silica content. These basalts contain a little more silica than average basalts and average spilites (table II, columns 5, 6, 7, 8), evidently because of the secondary silica and silicates in some of the amygdales. Generally, the silica contents in Central Pacific basalts (table II, column 10) and the Aitape basalts compare favourably, while those from Circum-Pacific localities (table II, columns 13, 14, 15) are a little variable.

Lime and magnesia are comparable in amount in the several amygdaloidal basalts of Aitape, but not in the basalts from the same area. The rather high magnesia content is accounted for by the abundance of chloritic and serpentinous material throughout the amygdaloidal basalts. In the more normal basalts of Aitape, the excess of lime over magnesia is of the same order as in Central Pacific basalts and Circum-Pacific basalts.

The presence of approximately twice as much Fe_2O_3 as FeO in all the analysed Aitape basalts, is a function of the large quantity of grains and skeletal crystals of magnetite and accompanying hematite in their groundmasses. These basalts show the same characteristics as the Aitape andesites (table III, columns 1 and 2) in containing Fe_2O_3 in excess of FeO, whereas the reverse holds in the average basalts and average spilites. The Circum-Pacific basalts likewise contain Fe_2O_3 in excess of FeO, but not the Central Pacific (Hawaiian) basalts. The Aitape basalts, however, are generally low in total iron, the amygdaloidal more so than the normal varieties, whereas both the Circum-Pacific and the Central Pacific basalts contain approximately twice as much total iron as the Aitape basalts, evidently because the augite in the Aitape basalts is a less iron-rich variety than in most other Pacific basalts.

Total alkalies in the Aitape and Pacific basalts show certain anomalies when individual values are considered, only one of the Aitape basalts (i.e. from Rohm Point proper) being as low in alkalies as

Central Pacific basalts, the others being similar to the general run of Circum-Pacific basalts. The average value for total alkalies in the Aitape basalts (4·66%) is a little higher than for average basalts (4·63%), but lower than for average andesites (5·5% and 6·4%—table III, columns 4 and 5) and close to average spilites of some authors (table II, column 6). The average value is more comparable with the average for Circum-Pacific basalts than with the value for Central Pacific basalts. A little of the soda (likewise some of the potash and lime) in some of the Aitape basalts, such as the St. Anna Plantation basalt, has to be apportioned to chabazite in the amygdales, but as this mineral is relatively rare, the rock itself must be richer in soda than any other member of the analysed Aitape volcanic rocks, whether basalts or andesites, and so is closely related to the spilitic rocks.

Total lime and magnesia in the Aitape basalts shows a range from 14·25% to 18·17%, but is closer to average basalt (15·12%—table II, column 9) than to average andesites (9·70% and 8·0%—table III, columns 4 and 5), and closer to Central than to Circum-Pacific basalts, although little different, on the average, from either.

Aitape basalts are much poorer in titania than average basalts, average spilites and Central Pacific basalts.

The ejected block of hornblende gabbro (table II, column 11) was regarded by Richarz (1910) as chemically similar to gabbro from Langenlois in Lower Austria.

ANDESITIC ROCKS.

In the Aitape district, andesitic rocks occur principally as agglomerates. The texture and the amounts and nature of pyroxene and amphibole minerals in andesite fragments forming the Tepier and Tumleo Island agglomerates, are markedly variable. Many of the fragments are amygdaloidal porphyritic augite andesite, with occasional representatives of augite andesite, hornblende-augite andesite, porphyritic augite andesite, pyribole andesite, porphyritic hornblende-augite andesite and porphyritic augite-hypersthene andesite.

The texture of the andesites is typically hyalopilitic, the groundmass in most varieties being microlitic, with abundant glass containing numerous laths of plagioclase. A few of the andesites have pilotaxitic texture, due to microlitic felspars developing almost to the exclusion of glass. A number are porphyritic.

Augite Andesite. Uncommon, and only occurring in the agglomerate of Solyaliu Hill on Tumleo Island, this rock has a cryptocrystalline to glassy groundmass with abundant minute grains and clots of magnetite (partly altered to hematite), larger twinned-zoned andesine laths (some with cores of acid labradorite), abundant fresh augite, occasional altered hypersthene and rare hornblende. Infilled vesicles are few and small.

The augite is the pale yellow to yellowish-green variety common to the Aitape andesites generally, and is occasionally zoned. Pseudomorphs after hypersthene consist mainly of opaline silica with a little chlorite and numerous apatite rods, while a few consist of serpentinous products showing relic pyroxene cleavage. Hornblende is mostly replaced by deuteric alteration products. In rare crystals, an inner core of fresh, pleochroic hornblende is surrounded by a reaction corona. The corona is composed of an inner zone of unaltered magnetite crystals and a broad outer zone of indefinite, pale grey to greenish coloured fibres and minute plates. Larger plates, that evidently consist of similar material to these fibres and small plates, occur in a replaced microphenocryst and consist of secondary, pale coloured amphibole.

Porphyritic Augite Andesite. An uncommon constituent of the Solyaliu Hill agglomerate, this rock has a crypto- to micro-crystalline and glassy base containing secondary iron oxides and hydroxides that impart a light reddish-brown colour to the groundmass. Abundant colourless laths of plagioclase and less frequent, pale yellow to almost colourless prisms of pyroxene, form a striking contrast to the pinkish coloured groundmass in which they are set with a marked fluidal alignment.

Augite forms unaltered phenocrysts a little larger than the plagioclase laths and up to 1 mm. long. Altered hypersthene prisms are the same size as the plagioclase laths and occasional microphenocrysts are a little larger than the augite crystals.

Richarz (1910, p. 433) noted that the hypersthene crystals in some of the Tumleo Island volcanic rocks, had been replaced by opal and that chlorite had penetrated the opal. That the replaced mineral (see figure 9B) was originally hypersthene, is proved by accumulated evidence from several of the andesitic rocks, thus:

(*a*) unaltered hypersthene occurs in other Aitape andesites,

(*b*) 8-sided cross sections and prisms with characteristic pyroxene form, are replaced by opal in the porphyritic augite andesite,

(c) unaltered augite occurs in the same rocks as replaced hypersthene, and

(*d*) hypersthene remnants occur in partially opalized pseudomorphs in porphyritic augite-hypersthene andesite from Solyaliu Hill.

Original hypersthene groundmass prisms and microphenocrysts in the porphyritic augite andesite, are now largely isotropic pseudomorphs, with here and there a little secondary quartz left as relics of hypersthene alteration (figure 9B). Hypersthene pseudomorphs are more common than fresh augite microphenocrysts and unlike them, have been considerably corroded by groundmass constituents in places.

Unaltered plagioclase laths with sharply defined crystal outlines, show multiple twinning, sometimes combined with normal continuous zoning, sometimes normal discontinuous (varying from acid to basic andesine) and rarely oscillatory or oscillatory reverse chemical zoning. A few andesine crystals contain central cores of opal (figure 9A), indicating replacement of the more lime-rich portion. In rare examples, originally lime-rich outer zones have been replaced by opal. Areas of opaline silica are sometimes wedged between partially welded-on andesine crystals.

Amygdaloidal Porphyritic Augite Andesite. This rock, from Tepier East Hill (488′), is a common constituent of the agglomerate and one of the few Aitape andesites containing vesicles infilled with secondary minerals. Primary minerals are esssentially the same and the groundmass constituents similar to porphyritic augite andesite from Solyaliu Hill.

Double pseudomorphs after hypersthene are characteristic of this rock, several opaline silica replacements of hypersthene crystals themselves being subsequently replaced, completely or partially (figure 9E), by calcite. Calcite veinlets that link up several replaced pseudomorphs, pass around augite phenocrysts, cut through groundmass constituents, through fresh andesine laths without displacing them, but swell out into knots within the laths. Rather more common than calcite, olive green, pleochroic delessite is often spherulitic, sometimes fibrous, and occurs in many parts of the rock, including vesicles and altered minerals.

Andesine and augite crystals remain unaltered. Brown to purplish coloured, pleochroic apatite prisms are occasionally associated with clots of augite. One zoned plagioclase phenocryst in this rock, has a core of basic labradorite surrounded by 30 narrow chemical zones ranging from acid labradorite to basic andesine in normal discontinuous zoning. Otherwise, the andesine crystals are similar to those in the porphyritic augite andesite from Solyaliu Hill.

Hornblende-Augite Andesite. Occurring at Tepier East Hill (456′), this rock has a dusty, grey, micro- to crypto-crystalline groundmass containing numerous grains and well-developed crystals of magnetite largely replaced by hematite, pseudomorphs of hematite after hornblende, laths of andesine and prisms of yellowish-brown, zoned augite.

The plagioclase is largely acid andesine, and as in the Mt. Bogana andesites on Bougainville Island (Baker, 1949), the number of zoned-twinned crystals is greater in hornblende-bearing than in augite andesite. A few border crystals are welded-on to larger andesine crystals. Zoning is commonly oscillatory normal, ranging from basic to acid andesine. Continuous normal zoning is common, oscillatory reverse zoning rare.

Small hornblende prisms are altered to hematite, but phenocrysts occasionally have unaltered, pleochroic cores enveloped by broad coronas of deuterically produced magnetite, more or less oxidized to hematite.

Much of the augite differs from the general type encountered in other Aitape andesites, in being yellowish-brown, non-pleochroic, with dark brown rims surrounding occasionally zoned cores (figure 9C). The zones extinguish at similar angles (34°) and in each crystal, are marked by colour differences only. Lighter coloured, pale yellow, non-zoned augite of a type characteristic of the Aitape volcanic rocks generally, is uncommon in the hornblende-augite andesite.

Coloured, pleochroic rods of apatite up to 1 mm. in length, appear fibrous due to regularly arranged inclusions. The pleochroism varies from brown to pale purple in some crystals, pink to pale pink in others.

The few vesicles in the rock are infilled with cryptocrystalline and opaline silica.

Porphyritic Hornblende-Augite Andesite. A common type at Solyaliu Hill, this rock has a microcrystalline groundmass with numerous magnetite crystals, oligoclase-andesine laths in pronounced fluidal alignment, abundant larger andesine laths, hornblende and augite phenocrysts, pseudomorphs after hypersthene and a few infilled vesicles. Fresh, strongly pleochroic cores of brown hornblende are surrounded by broad, well-developed reaction coronas (figure 9D). Smaller hornblende crystals are replaced by material like that in the coronas. Formed by deuteric alteration of peripheral regions of the hornblende, the coronas consist of secondary, iron-stained fibres arranged normal to the outer surfaces, with occasional unaltered and partially altered magnetite grains. Some hornblende crystals with coronas, show corrosion by groundmass constituents (figure 9D), portions of which are in turn partially replaced by opaline silica and chlorite. A few hornblende cores are entirely replaced, leaving only punctured sheaths of alteration products around kernels composed partly of groundmass constituents, partly of opaline silica with accompanying delessite.

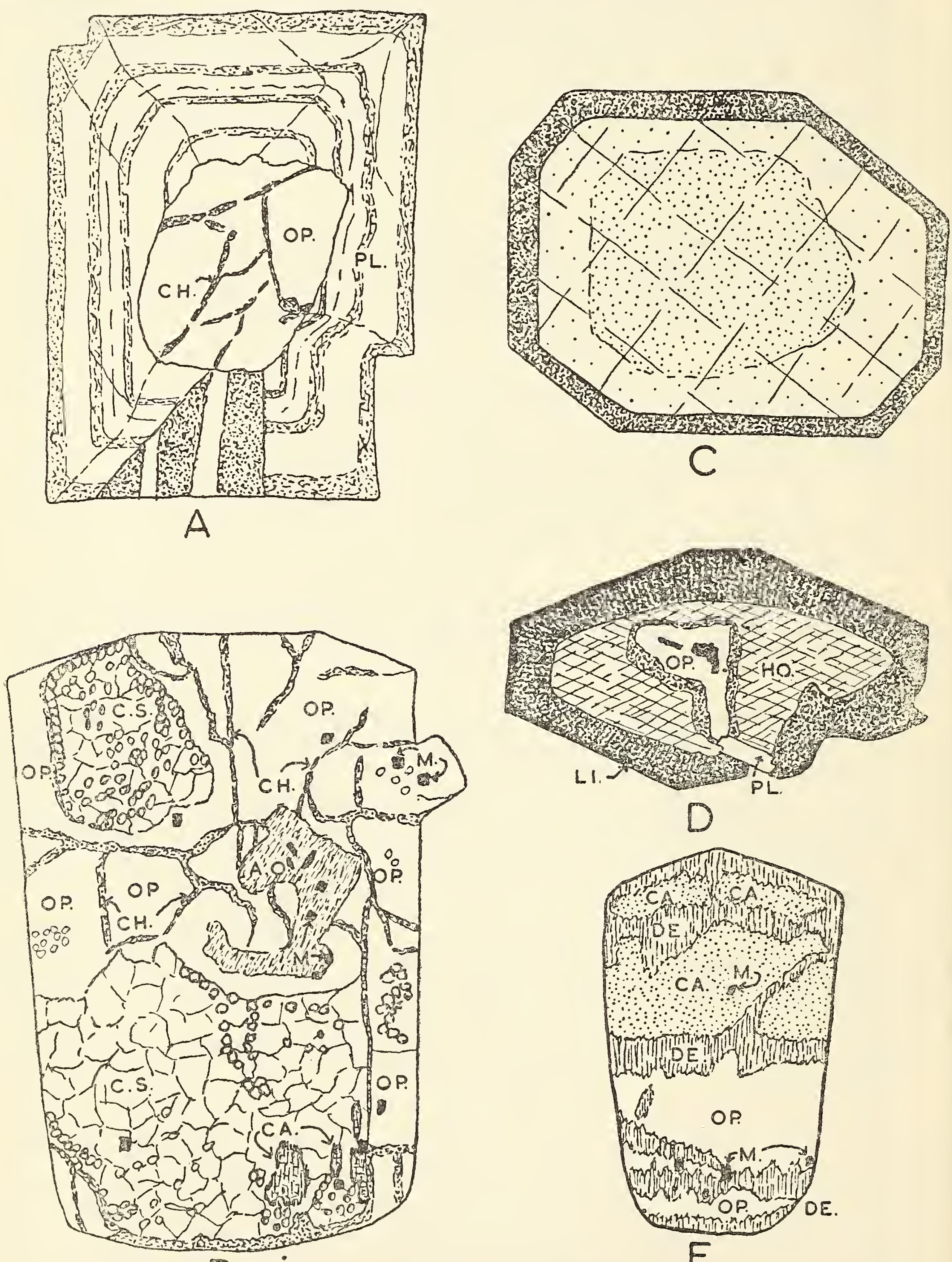

Figure 9.—Sketch Diagrams of Replaced and Zoned Minerals from the Aitape andesites.

A.—Zoned andesine with lime-rich core replaced by opal. Outer and similarly shaded zones extinguish at 11°, others at 32°. Zoning is discontinuous oscillatory. Crystal 0·25 mm. long in porphyritic augite andesite from Solyaliu Hill, Tumleo Island.

B.—Silica-replaced hypersthene crystal showing altered (?) olivine centre and areas of crystalline and opaline silica. Globular and micro-botryoidal growths of opal occur in the crystalline silica. Chlorite along cracks and cleavage directions of the original hypersthene and small amount of calcite present (at bottom of pseudomorph). Dark patches are magnetite. Crystal 1·1mm. long from porphyritic augite andesite at Solyaliu Hill, Tumleo Island.

C.—Dark brown rim of optically continuous augite, sharply delineated from yellowish-brown core of augite having a slightly darker coloured central region. Crystal 0·25 mm. across in hornblende-augite andesite from Tepier East Hill (456′).

D.—Reddish-brown hornblende with well-developed corona of fibrous secondary mineral stained throughout with iron oxide. Corona broken through (see bottom of sketch) by groundmass constituents and part of the interior of fresh hornblende replaced by opal and chlorite. Crystal 1·25 mm. long in porphyritic hornblende-augite andesite from Solyaliu Hill, Tumleo Island.

E.—Hypersthene microphenocryst replaced by opal and fibrous delessite, and portion subsequently replaced by calcite. Crystal 0·50mm. long in amygdaloidal porphyritic augite andesite from Tepier Hill (488′).

KEY TO LETTERS.

A.O. = altered (?) olivine.	Pl. = plagioclase (andesine).
CH. = chlorite.	CA. = calcite.
DE. = delessite.	C.S. = crystalline silica.
LI. = limonite.	HO. = hornblende.
OP. = opal, in part with chlorite.	M. = magnetite.

Phenocrysts of pale yellow augite have in parts reacted with the groundmass to form narrow, but infrequent reaction coronas of pale green hornblende.

Pseudomorphs of opaline silica after hypersthene are partially invaded along cracks by chloritic matter. Some contain crystalline and crypto-crystalline silica enclosing globular and micro-botryoidal opal. A feature of the pseudomorphs is that practically all the apatite content of the rock is located in them.

Andesine laths are fresh and typically the same as in other Aitape andesites. Larger laths characteristically combine zoning and twinning in the same crystal. They also contain more inclusions than usual of chloritized and opalized earlier products of crystallization, often dispersed throughout the core regions which are surrounded by jackets of clear andesine.

Opaline silica infills the majority of the few, small irregularly shaped vesicles and is often fringed by delessite (cf. Richarz, 1910, pp. 422-423). Occasional vesicles contain crystalline silica with minutely globular opal.

PORPHYRITIC AUGITE-HYPERSTHENE ANDESITE. This rock has only been observed at Solyaliu Hill on Tumleo Island, where it forms a volcanic neck (figure 6). Its groundmass is microcrystalline and a little coarser than any other Aitape andesite, also being crowded with grains and clots of magnetite. The weathered rock is pink to brown from oxidation of practically all the magnetite in the groundmass.

Phenocrysts of augite up to 10 mm. across are more strongly coloured greenish-yellow than in the majority of Aitape andesites. They often contain numerous cubes of magnetite and occasional prisms of hypersthene, indicating later crystallization than these minerals.

Unenclosed hypersthene crystals smaller than the augite, are relatively common as microphenocrysts. Few have been replaced by delessite—opaline silica growths in areas where these secondary minerals are locally well-developed. A few such pseudomorphs contain unreplaced remnants of pleochroic hypersthene.

Vesicles are mainly infilled with delessite and a little opal. Andesine phenocrysts, smaller than the augite phenocrysts, are numerous with zoned-twinned crystals prominent. One such plagioclase phenocryst with 56 narrow chemical zones, shows a range from acid to basic andesine in discontinuous normal zoning.

Pyribole Andesite. Containing hypersthene, augite, hornblende and xenocrystal biotite, this andesite is an uncommon component of the Tepier Plantation agglomerates. A specimen from the lower levels of Tepier East Hill (456′) has a much clearer glassy groundmass than most Aitape andesites, containing few microlites and few magnetite grains. Magnetite forms prominent clots and cubes larger than normally, thus accounting for the distinct shortage of minute magnetite grains in the glassy matrix. Perlitic cracks (normally due to rapid cooling), are characteristically developed in the clear glass surrounding the larger magnetite crystals, but not around any other minerals in this rock.

Hypersthene, the more abundant pyroxene present, forms prisms and occasional microphenocrysts. Augite is of similar size, but less frequent. Unaltered hornblende prisms are common, while occasional phenocrysts are twice the size of pyroxene microphenocrysts.

Numerous andesine crystals range from groundmass laths to crystals of phenocrystal dimensions. Combined polysynthetic twinning and chemical zoning is a common feature. Some zoned crystals range in composition from acid labradorite to acid andesine. Several groups of andesine crystals indicate growth by welding-on as in the Torokina River andesites on Bougainville Island (Baker, 1949, p. 254). Small plagioclase laths (originally attached border crystals), incorporated in the structure of one larger, zoned crystal, are more or less optically continuous with the larger crystal, and are made evident by small refractive index differences along lines of attachment and by small variations in extinction. One or two retain traces of zoning independently developed prior to welding-on.

All constituents of the pyribole andesite are unaltered. A few minute rods of clear apatite and rare, small prisms of hornblende are distributed at random in some of the andesine crystals. Vesicles are scarce and infilled with delessite.

The pyribole andesite contains rare clots of hypersthene-hornblende-magnetite and occasional clots of xenocrystal biotite. Accompanying the biotite clots are apatite and iron ore minerals. One coarse-grained clot, consisting of biotite attached to oligoclase, evidently represents a small inclusion of the country rock through which the andesite was emitted. In contact with oligoclase, the biotite was protected from attack by the host lava, but in contact with andesite groundmass, reaction fringes composed of small, colourless plates and prisms of indefinite character were formed. One embayed xenocryst of biotite, surrounded by a discontinuous reaction zone, is embedded in a pale violet-grey, weakly birefringent, fibrous matrix, alien to the enveloping groundmass constituents of the andesite and with a crude radial arrangement. Along directions of elongation of the fibres, are many slender threads of iron ore minerals.

Elsewhere in the Tepier Plantation area, as in the 120′ high cliff of andesitic agglomerate 5 to 8 chains inland from the present shoreline, in the north-eastern portion of the outcrop, pyribole andesite has a rather more dusty, glassy base. The primary mineral content is of the same order of abundance and the mineral species are generally similar, even to the biotite xenocrysts with reaction borders as in the Tepier East Hill (456′) pyribole andesite.

CHEMICAL COMPOSITION OF THE ANDESITIC ROCKS.

Analysed andesites from the Aitape district (Richarz, 1910, p. 445) are listed in table III and compared with average andesites from several localities and with biopyribole andesite of recent origin in the Goropu Mountains of South-east Papua (Baker, 1946).

TABLE III.

—	1	2	3	4	5
SiO_2	59·39	54·02	55·83	59·3	60·8
Al_2O_3	16·73	14·82	16·23	16·6	17·3
Fe_2O_3	5·03	7·12	nil.	3·1	2·9
FeO	1·60	2·67	4·13	3·5	2·5
CaO	6·98	9·07	7·87	6·3	5·5
MgO	3·48	5·64	7·91	3·4	2·5
K_2O	1·32	0·71	3·80	1·9	2·4
Na_2O	3·18	2·63	2·30	3·6	4·0
TiO_2	0·72	1·60	1·14	0·7	0·6
MnO	0·10	tr.	0·11	0·1	0·1
H_3PO_4	tr.	tr.	n.d.	0·2	0·2
H_2O	1·52	1·92	1·01	1·3	1·2
Total	100·05	100·20	100·33	100·0	100·0

KEY TO TABLE III.

1.—Hornblende andesite, Tumleo Island, Aitape (anal. E. Ludwig—see Richarz, 1910, p. 445).

2.—Augite-hypersthene andesite, Tumleo Island, Aitape (anal. E. Ludwig—see Richarz, 1910, p. 445).

3. Biopyribole andesite (lapilli), Goropu Mountains, South-east Papua (anal. F. F. Field—see Baker, 1946, p. 23).

4.—Mean of twenty analyses of hypersthene and augite andesites (Osann—Rosenbusch, "Elemente der Gesteinlehre" (1923), p. 409, Stuttgart: E. Nagele).

5.—Mean of eighteen analyses of biotite and hornblende andesites (ibid.).

The TiO_2 in column 1, table III, is ascribed by Richarz (1910) to titan-rich hornblende and the TiO_2 in column 2, table III is regarded as being mostly in magnetite. However, examination of a polished surface of porphyritic augite-hypersthene andesite from Tumleo Island under a 1/10 Fl. oil immersion lens, does not confirm the observations of Richarz. Among the opaque minerals are abundant grains of hematite, and in occasional of these grains are narrow lamellae of ilmenite. The hematite is pseudomorphous after magnetite and some of the TiO_2 of the analysis is ascribed to the exsolved ilmenite lamellae. The remainder of the TiO_2 is accounted for by the presence of minute crystals of foxy-red to honey-yellow rutile, so small as to be only detectable under the oil immersion lens and scattered throughout the rock. In hornblende-augite andesite from this area, the TiO_2 is not due to titan-rich hornblende as concluded by Richarz, but arises from the presence of small rutile grains, numerous micrographic intergrowths of rutile and hematite and occasional granular intergrowths of ilmenite and hematite, the hematite in the intergrowths being pseudomorphous after magnetite.

The chemical composition of the hornblende andesite (table III, column 1) closely approximates the mean composition of twenty hypersthene and augite andesites (table III, column 4), but is slightly lower in silica, alumina and total alkalies and a little richer in iron, lime and magnesia than the average of eighteen biotite and hornblende andesites (table III, column 5). Richarz (1910) regarded the hornblende andesite from Tumleo Island, Aitape, as chemically similar to andesites from Rincon de la Vieja, Costarica and from Tuscan Buttes, Lassen's Peak region, California. This is of some interest in view of the comparable character, chemically, of basalts from California and basalt from Pultalul Hill, Aitape, and indicates that both the andesitic and the basaltic suites in these widely separated Circum-Pacific localities, thus have much in common.

The Tumleo Island andesites typically have lime in excess of magnesia and soda in excess of potash, the normal for andesites generally (cf. averages in table III, columns 4 and 5). Total iron is rather higher in augite-hypersthene andesite (table III, column 2) than usual, alumina a little lower. The residual glass forming the groundmass of the andesites, is evidently enriched in potash, since soda would have been used up in development of the andesine laths. The excess silica over and above the requirements of the silicates in the andesites, lies occult in the groundmass glass, just as in the biopyribole andesite lapilli (table III, column 3) from the Goropu Mountains, South-east New Guinea.

EJECTED BLOCKS.

Richarz (1910, pp. 434 and 436) described inclusions in the Tumleo Island volcanic rocks as (i) hornblende gabbro (see analysis, table II, column 11), consisting of hornblende and plagioclase with some biotite, magnetite and apatite, (ii) hornfels composed of biotite, magnetite, bytownite, quartz and hypersthene, the rock being impregnated with delessite with isotropic cores.

Other alien fragments ejected by the Lower Miocene volcano at Solyaliu Hill on Tumleo Island are largely gabbroic rocks similar to those of the basement complex as exposed in the Torricelli Mountains, and some blocks from the Lower Miocene limestones exposed on the northern flanks of these mountains. Gabbroic ejected fragments are fairly common and up to 6″ across. They consist of basic bytownite to anorthite, diallage, hypersthene, dark green hornblende (as partial rims to some of the pyroxenes), clots of magnetite and abundant opaline silica with chlorite which in parts have developed around the ferromagnesian minerals. The formation of such secondary material in the gabbroic rocks. evidently arose simply by virtue of these rocks being ejected fragments in association with similarly altered andesite fragments, the alteration having occurred in the late stages of Tertiary volcanicity. Gabbroic rocks from the Torricelli exposure of the New Guinea basement complex, remote from this Tertiary volcanism, were sampled from Afua village (figure 10) on the Driniumor River, 20 miles south-east of Aitape. These show only the usual alteration such as serpentinization, &c., and no development of opaline silica-delessite associations as in the Neogene andesitic rocks.

Similar, typical gabbro alteration to that at Afua, is also shown by gabbro and peridotite from near Babiang at the mouth of the Dandrawad River (figure 10), but hornblende-hypersthene gabbro and amphibolite from Matapau at the mouth of the Wakip River together with diorite from Rocky Point and Niap, show no alteration.

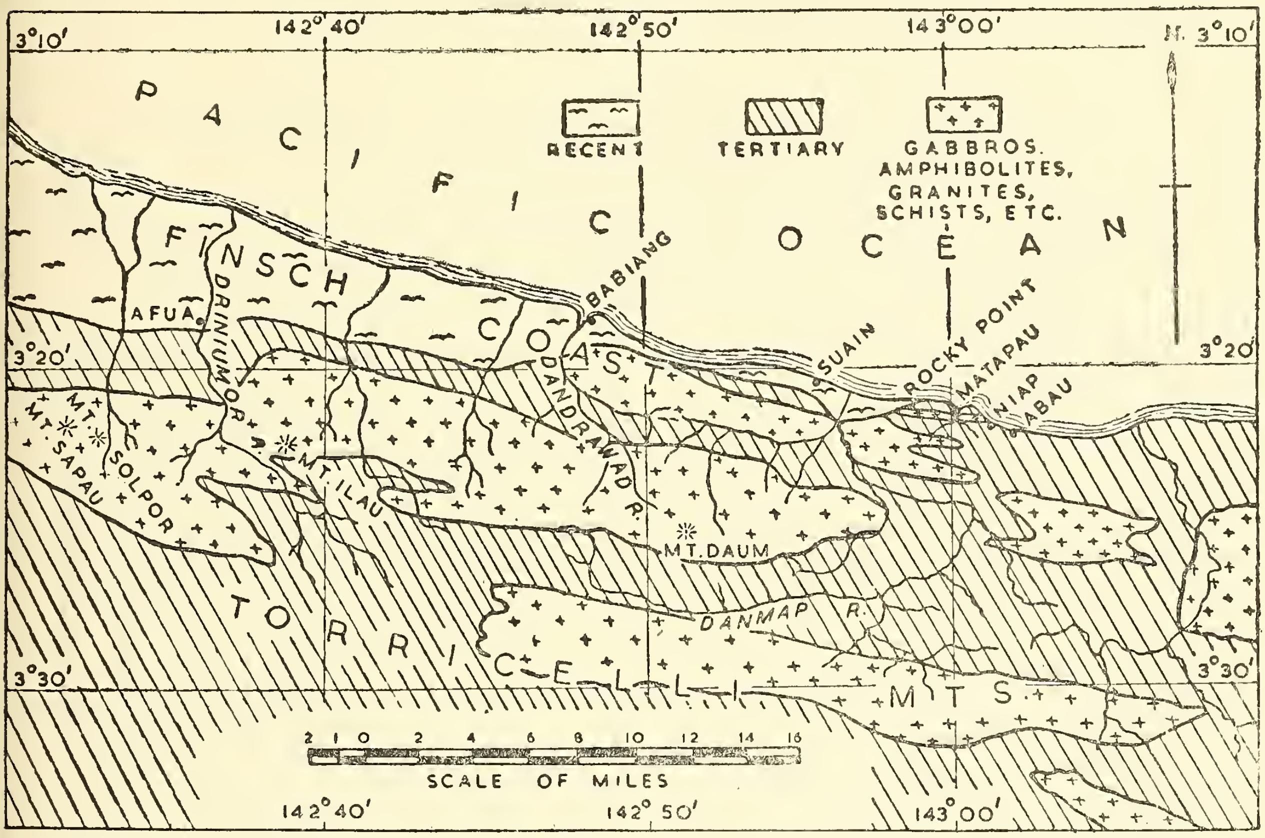

Figure 10.—Geological Sketch Map of Portion of the Northern Flanks of the Torricelli Mountains south-east of Aitape.

ALTERATION OF THE AITAPE VOLCANIC ROCKS.

Most of the Aitape volcanic rocks have been partly altered, as indicated in table IV. Alteration was partly late magmatic, partly due to solfataric action and the effects of hydrothermal agencies such as hot springs containing dissolved silica, and hot, circulating carbonated waters. Some alteration (e.g. of magnetite) was due to atmospheric agencies, some (e.g. of olivine and hornblende) to corrosive deuteric action early in the magmatic history of the rocks.

Table IV shows that few Aitape volcanic rocks escaped alteration of some sort. Those subjected to most alteration are (i) nearly all the more basic types, particularly amygdaloidal basalts, and (ii) among the intermediate types—characteristically the amygdaloidal andesite and hornblende-augite andesite in Tepier Plantation and porphyritic hornblende-augite andesite on Tumleo Island.

Early deuteric changes in the Aitape lavas are represented by complete alteration of olivine in basaltic types, development of reaction coronas around hornblende in porphyritic hornblende-augite andesite on Tumleo Island, complete alteration of hornblende in hornblende-bearing augite andesite on Tumleo Island and in hornblende-augite andesite from Tepier East Hill (456′), and production of occasional narrow reaction rims around a few augite crystals in porphyritic hornblende-augite andesite on Tumleo Island.

Late magmatic, evidently solfataric and hydrothermal alteration is represented by the infilling of vesicles with opaline silica, chloritic products (including delessite) and later calcite. Concomitantly pseudomorphs were developed where opaline silica, crystalline silica and chloritic material selectively replaced hypersthene. Of rather later development, are the occasional double pseudomorphs formed where calcite replaced some of the opaline silica pseudomorphs after hypersthene. Throughout these changes, the majority of the felspars and virtually all the augite remained unaltered.

TABLE IV.

SHOWING MINERAL ALTERATION OF THE AITAPE VOLCANIC ROCKS.

Mineral alteration or introduction.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Albite and albite-oligoclase developed				+	+										
Felspars completely altered	+														
Olivine completely altered	+	+	+	+	+	+									
Secondary minerals in amygdales	+		+	+	+	+			+		+	+			
Augite partially altered ..				+					+						
Augite with reaction coronas											+				
Hornblende with reaction coronas										+	+				
Some hornblende completely altered							+			+	+				
Hypersthene completely altered							+	+	+		+	+			
Groundmass partially altered				+	+				+		+				
Magnetite altered.. ..						+	+			+	+	+		+	
Biotite (xenocrystal) altered														+	+
Escaped alteration ..													+*		+

(+* indicates a little mineral matter introduced into a few vesicles.)

KEY TO TABLE IV.

1.—Amygdaloidal basalt, Lower Flow, 200′ Rohm Point Hill.

2.—Basalt, 223′ Rohm Point proper.

3.—Amygdaloidal basalt, Upper Flow, 270′ Rohm Point Hill.

4.—Amygdaloidal basalt, St. Anna Plantation.

5.—Amygdaloidal basalt, cliff 200′, Lapar Point Hill.

6.—Basalt, Pultalul Hill.

7.—Augite andesite, Solyaliu Hill, Tumleo Island.

8.—Porphyritic augite andesite, Solyaliu Hill, Tumleo Island.

9.—Amygdaloidal porphyritic augite andesite, Tepier East Hill (488′).

10.—Hornblende-augite andesite, Tepier East Hill (456′).

11.—Porphyritic hornblende-augite andesite, Solyaliu Hill, Tumleo Island.

12.—Porphyritic augite-hypersthene andesite, Solyaliu Hill, Tumleo Island.

13.—Porphyritic augite-hypersthene andesite (unweathered portion of volcanic neck) Solyaliu Hill, Tumleo Island.

14.—Pyribole andesite, old sea cliffs, 120′ high, Tepier Plantation, north-eastern end of eastern outcrop.

15.—Pyribole andesite, lower levels, Tepier East Hill (456′).

It is uncertain whether the formation of the soda-rich amygdaloidal types by soda replacement of lime in the transition of basic to albitic felspar in the earlier-formed, more basic lavas at Aitape, occurred at this or an earlier stage. Undoubtedly this phase of lava alteration occurred after the development of the primary minerals, as the albite and albite-oligoclase are not primary in the sense that the lime-plagioclase is primary. Neither are they secondary in the sense that the opaline silica-calcite-delessite infillings of amygdales and replacements of other minerals are secondary. The fact that augite remains fresh in the soda-rich types, suggests that the albitized felspars have not been formed by the action of external solutions on already consolidated basalt, but more likely by reaction with a sodic fraction developed in the magma, during the end phases of crystallization.

Replacement of the minute groundmass plagioclase laths in the amygdaloidal basalt from 200′, Lower Flow, Rohm Point Hill (table IV, column 1), by crypto-crystalline material, is also a late secondary development.

Changes due to ordinary processes of atmospheric weathering, are evidenced by the alteration of magnetite to hematite and limonite, both in the groundmass of some of the andesitic rocks and in the coronas of marginally altered hornblende in the hornblende-bearing andesites. The alteration to hematite may have commenced during phases of metasomatic alteration.

The magnesia, lime and silica requisite for the formation of the abundant secondary minerals—chlorite, delessite, calcite, opal, crypto-crystalline silica and quartz, that form pseudomorphs and small veinlets, infill vesicles and replace parts of the groundmass in the various Aitape volcanic rocks, were evidently derived from the altered olivine and partially albitized lime-felspars in the basalts.

COMPARISONS OF THE AITAPE VOLCANIC SUITE WITH OTHER NEW GUINEA VOLCANIC AREAS.

Andesitic and basaltic rocks from various parts of British New Guinea, vary in age from Tertiary to Recent. Specimens from (i) Sogeri, north-east of Port Moresby, (ii) Dobodura, north-east of Mt. Lamington, (iii) Goodenough Island and Urasi Island in the D'Entrecasteaux Group, (iv) Kesup, four miles south of Madang and (v) the Goropu Mountains near Collingwood Bay*, reveal various types of basalts and andesites of Tertiary, Pleistocene and Recent age, with at least two, possibly three marked periods of volcanic activity during the Tertiary period.

D'Entrecasteaux Group. The more basic members of the Aitape volcanic series bear little resemblance to the relatively young basaltic rocks at Malafua Creek and Bolu Bolu on Goodenough Island in the D'Entrecasteaux Group, south-eastern New Guinea (Baker and Coulson, 1948). At these localities, the flows are fresh, porphyritic olivine basalts, sometimes iddingsitized and lacking the amygdales so characteristic of the Aitape basalts, although some are vesicular in parts.

Many features of some of the andesites at Aitape, however, are repeated on Urasi Island and the neighbouring islands of the Amphlett Group (Baker and Coulson, 1948, p. 661), where hornblende andesites are hypersthene-bearing as in so many of the andesitic volcanic rocks erupted around the fringe of the Pacific Basin. They are likewise

* These localities are marked on figure 1.

crowded with similarly twinned-zoned andesine crystals, have a microcrystalline groundmass that is in parts glassy and typically show similar reaction coronas around the larger hornblende phenocrysts as in the hornblende-bearing representatives of the Aitape andesites. These coronas are similarly altered to form broad bands of limonite and hematite. Porphyritic hornblende-augite andesite from Solyaliu Hill on Tumleo Island, near Aitape, has many characteristics in common with porphyritic hornblende andesite from the west side of Urasi Island.

Sogeri. The Upper Tertiary volcanic agglomerates from Sogeri, north-east of Port Moresby, consist largely of blocks of porphyritic olivine basalt up to 2 or 3 feet in size, averaging 9 inches and with smaller constituents 1 to 2 inches across. All the component fragments of the agglomerate appear to be volcanic, no ejected fragments of alien rock types being noted. The fragments are not particularly vesicular and there is a notable absence of fine ash constituents. The most common components are basaltic rocks that have little, if any, resemblance to the Aitape basalts, but among these components, occur occasional fragments of pyribole andesite not unlike the Aitape pyribole andesite.

Dobodura. Hypersthene andesite, augite-hypersthene andesite, pyribole andesite, hornblende andesite and hornblende-augite andesite represented among volcanic pebbles derived from the Mt. Lamington Pleistocene volcanics and collected from the Dobodura airstrip area, are unlike the similarly named varieties of andesite at Aitape in several respects. They are coarser-grained, having larger phenocrysts of pyroxene, amphibole and felspar in rather coarser groundmasses. There are a few similarities, however, in that the Dobodura volcanic rocks have incipiently developed hornblende reaction coronas in the pyribole andesite, broad well-developed reaction coronas and completely replaced hornblende microphenocrysts in the hornblende andesite and occasional pseudomorphs of opal after hypersthene. The hornblende reaction coronas and completely replaced hornblende microphenocrysts, however, are little weathered and are largely magnetite rather than hematite as at Aitape and in the islands of the Amphlett Group.

Kesup. The Kesup volcanic rocks are waterworn pebbles from the ford over the Gum River, four miles south of Madang. They were presumably derived from the Lower Miocene volcanic rocks of the Adelbert Mountains. Hornblende-augite andesite from Kesup has a microcrystalline groundmass without any glass, and contains much larger phenocrysts of hornblende and plagioclase than the Aitape hornblende-augite andesite. No hornblende reaction coronas were formed in the Kesup example and groundmass andesine laths are lacking. Small differences occur between pyribole andesite from Kesup and Aitape, the Kesup specimen containing in addition a considerable amount of quartz (mainly in the groundmass). If present in the Aitape pyribole andesite, excess silica lies occult in the glassy groundmass. The Kesup rock contains more numerous pleochroic apatite crystals. Kesup andesites are more crystalline than Aitape andesites, but are generally mineralogically similar to them, although opaline silica-chlorite pseudomorphs after hypersthene are conspicuously absent at Kesup.

Goropu Mountains. Pyribole andesites at Aitape bear little resemblance to vesicular lapilli of porphyritic biopyribole (biotite, augite, hornblende, olivine) andesite recently ejected in the foothills of the Goropu Mountains (Baker, 1946). Aitape andesites are not as basic and do not contain fresh or altered olivine. Where biotite is present as in pyribole andesite from Tepier Plantation near Aitape, it is xenocrystal in origin; the biotite in the Goropu rock is a primary constituent of biopyribole andesite. Hypersthene has not been observed in the Goropu Mountains andesitic lapilli, but is commonly present in several of the Aitape andesites. The Aitape rock is not nearly as vesicular as biopyribole andesite from the Goropu Mountains.

GENERAL REMARKS ON THE VARIOUS VOLCANIC SUITES.

The Aitape, Adelbert Mountains and Sogeri volcanic rocks are all shown as Upper Tertiary on the geological sketch map of Eastern New Guinea (Montgomery, Osborne and Glaessner, 1945). The Aitape and Adelbert Mountains volcanic rocks are Lower Miocene, while the Sogeri volcanic rocks are generally considered to be Pliocene.

The Dobodura-Mt. Lamington volcanic rocks are shown as Pleistocene on the geological sketch map of Eastern New Guinea, and the Goropu volcano is historically recent (Baker, 1946). The petrographic comparisons and contrasts between these various outcrops add nothing new to the above age relationships. Mt. Lamington, however, re-erupted violently during the early part of 1951, having apparently remained dormant for a period beyond the legendary knowledge of the local inhabitants. Eruption took the form of explosive activity, with the production of *nuées ardentes* and much ash and gas, causing scorification of the vent*.

Among the Aitape volcanic rocks, the andesites are more like some of the younger volcanic rocks of the Mt. Lamington area and like those of Urasi Island, but the basaltic types have no near counterparts among basalts from the areas examined, being localized types verging on basic andesites and becoming sodic in parts.

FORMATIONAL AND CRYSTALLIZATION HISTORY OF THE AITAPE VOLCANIC ROCKS.

Volcanicity in the Aitape district commenced with an essentially effusive stage and little associated explosive activity. Submarine flows were extruded on to a sea floor of Tertiary sediments including limestones containing tuffaceous material in parts. The time of extrusion was presumably during the initial phases of the development of the Neogenic-Quaternary Inner Volcanic Arc of the Bismarck Archipelago. The site was the southern fringe of this arc, i.e. on the edge of the north-eastern down-warped (Miocene) areas off the north-westerly trending coastline of North-east New Guinea. The volcanic rocks commenced to form here soon after the initiation of the downward movements in the formation of the Bewani Geosyncline (Beltz 1944, p. 1453). Geosynclinal conditions resulted in the accumulation of considerable thicknesses (15,000′) of the Miocene-Pliocene deposits now constituting the Neogene foothills on the northern flanks of the Torricelli Mountains, part of which is shown in figure 10. During periods of limestone formation towards the bottom of the geosynclinal sediments, volcanic ash was emitted from time to time, and incorporated in the accumulating limestones, thus forming tuffaceous limestones (see Nason Jones, 1920-1929) which contain the interbedded Aitape lavas.

* These statements on the type of eruption are deduced from press reports only.

No doubt, the same phase of volcanicity along this arc, formed the Upper Tertiary volcanic rocks of the Serra Mountains, the Adelbert Mountains and the Finisterre Mountains*. The latest phases of volcanicity constitute the *en échelon* arcs extending from Kairiru Island to New Britain (figure 2).

The evidence already set out shows that the earliest lava flows of the Aitape volcanic suite were partly submarine and in parts somewhat enriched in soda, and though they may not be true spilites in the strictest sense of the term, portions are closely allied to albitized basalts. Some of these lavas were evidently derived from a magma fraction more basic and locally as rich or richer in soda than the later formed magma fractions that produced the Aitape andesites (cf. tables II and III). Such a fraction, however, was as basic, although richer in soda, than the magma producing the associated more normal basalt flows at Aitape.

Changes involving alteration of the lime-rich felspars in the formation of spilitic rocks, are usually regarded as occurring at a late stage in magmatic cooling history, and not subsequently to consolidation in the generally accepted sense (cf. Hatch and Wells, 1926, p. 297). Significant albitization of basaltic rocks by resurgent water has been suggested by Daly (1933, p. 420), but the fact is not overlooked that spilitic pillow lavas often show evidence of having been erupted through wet sediments and solidified in the presence of abundant steam. Considerable thicknesses of wet sediments had already accumulated in the Bewani Geosyncline prior to the effusive stages of Lower Miocene volcanicity.

The autolytic development of the soda-rich plagioclases in spilitic pillow lavas, requires abundant volatiles, but the source of these volatiles is difficult to prove at Aitape, where the partial soda-enrichment of the basic flows is so localized among the limited amounts of basalt emitted. Surging of soda-rich volatiles could possibly have occurred in the rising magma below the level of active sedimentation, but the conclusion regarding the more fundamental question of the nature of the magma in which such concentration could take place, is in agreement with that of Daly (1933) and Eskola (1925), who hold that typical spilites are deuteric products of ordinary basalts. Gilluly (1935) concludes that spilites are not derived from an independent magma, that the albitization is caused by hydrothermal solutions and that hydrothermal alteration is autolytic, closely following in time the consolidation of the rocks. Sundius (1930) pointed out that British authors also believe that spilitic rocks were altered by an autometamorphic (i.e. autolytic) change, Na_2O and CO_2 being retained in solution during solidification of the magma, after which they acted upon the minerals of the rocks; but the high Na_2O content is regarded as a necessary component of the original magma.

The evidence from the Aitape soda-rich basalts provides no exceptions to these ideas concerning the formation of spilites, and adds little that is new to the problem. Throughout geological history, albitic rocks of the spilite suite have characteristically developed in the geosynclines (Holmes, 1927, p. 263), and the soda-enriched portions of the Lower Miocene basaltic rocks at Aitape are no exception, being associated with an Upper Tertiary geosyncline—the Bewani Geosyncline.

* These localities are marked on figure 1.

The Aitape basalts followed a normal order of crystallization, and eventually gave place to augite-, hypersthene- and hornblende-bearing andesites in the later stages of eruptivity. This association is similar to the relationships of spilites and andesites in the Arenig centre of Ordovician lavas in North Wales, and as propounded for this area (see Hatch and Wells, 1926, p. 438), likewise in the much younger volcanic suite of the Aitape district in New Guinea—the change in facies of the volcanic products from sodic (spilitic) to calc-alkaline (andesitic) types, goes hand in hand with the fact that locally, the volcanic materials built up above sea level. By this time, the nature of the eruptivity at Aitape had become essentially explosive, forming the thicker deposits of andesitic agglomerates. The constituents of the mixed assemblage of ejectamenta in the agglomerates, and the associated andesitic lava flows, represent various phases of minor differentiation in a magma that had passed from basic to one of intermediate composition. Products of andesite of several mineralogical types were built up to greater thicknesses than was obtained by the essentially effusive basaltic phase. Evidently submarine explosive activity had occurred before and continued afterwards, but to lesser extents and under deeper water conditions, thus accounting for the presence of tuffaceous material incorporated within the marine limestones (tuffaceous limestones) that are recorded by Nason Jones (1920-1929) as being interbedded with Aitape volcanic rocks.

The order of formation of the several types of andesites is not clear from the field evidence, and it is only certain that the last to form was the volcanic neck of porphyritic augite-hypersthene andesite at Solyaliu Hill on Tumleo Island. Petrological evidence indicates that in the other andesites, hypersthene crystallized after the primary accessory minerals magnetite and apatite, but prior to augite and plagioclase. Some of the augite crystallized after the hypersthene, then followed hornblende, then the rest of the augite and then much of the plagioclase felspar. It would thus appear that most hypersthene-bearing andesites were among the earlier-formed products of the andesite suite at Aitape, although the volcanic neck rock at Solyaliu Hill which is hypersthene-bearing, was evidently the last andesite emitted from Tumleo volcano.

The evidence accrued from this investigation, shows that at various times and for various reasons, parts of the crystallized fractions of the andesitic magma were out of equilibrium with the enclosing melt, and the process of crystallization did not follow a normal sequence of events as in the basaltic phase. There is evidence of the probability of at least two periods of hypersthene formation—one in the early stages and one in the final stages of andesitic volcanicity. Oscillation from wet to dry conditions of crystallization seems to be indicated by the formation of some of the augite after crystallization of the normal intermediate variety of hornblende, and by the development of coronas containing hornblende around occasional of the earlier-formed augite crystals. Felspar formation occurred in marked phases due to changes in equilibrium at various stages, resulting in a final mixed assemblage of laths, microphenocrysts and phenocrysts with considerably divergent types of combined chemical zoning and twinning, and with variations in the nature and amount of earlier crystallized mineral inclusions.

The distribution and frequency of occurrence of the zoned and twinned plagioclase felspars (chiefly andesine) of phenocrystal and microphenocrystal dimensions in the andesitic rocks of Aitape, are indicated in Table V.

TABLE V.

ZONED-TWINNED PLAGIOCLASE FELSPARS IN THE AITAPE ANDESITES.

No.	Andesitic Rock.	Twinned-Zoned Felspars.	Zoned, Non-Twinned Felspars.	Twinned, Non-Zoned Felspars.	Other Zoned Crystals.
1	Augite andesite ..	common	occasional	very few	augite
2	Porphyritic augite andesite	common	common	few	
3	Amygdaloidal porphyritic augite andesite	common	few	occasional	
4	Hornblende-augite andesite	abundant	few	few	augite
5	Porphyritic hornblende-augite andesite	occasional	very few	common	
6	Porphyritic augite-hypersthene andesite	common	occasional	common	
7	Pyribole andesite ..	occasional	abundant	none	

Hornblende remained unaltered in some of the andesite fragments forming the agglomerates, but reaction coronas were developed around it and some crystals entirely replaced in other andesite fragments from the same locality. These unaltered, partially altered and completely altered hornblende crystals point to derivation during varying conditions in the magma, probably largely in the crater and conduit magma. The alteration apparently arose during effusive phases, when different levels of either the conduit or the cupola region were being tapped and added to the crater magma, where variations in the steam and water content were prevalent. Parts where the hornblende remained in equilibrium with the enclosing melt, were evidently free of excess active reacting materials, so that unaltered hornblende crystals could persist. Other parts were in a state of non-equilibrium as between hornblende and enclosing melt for a time, so that the fringes of the crystals were altered to produce reaction coronas surrounding fresh cores. Completely altered hornblende crystals in other andesitic fragments from the agglomerate, indicate origin in parts where volatiles were in greater concentrations for longer periods prior to ejection at the surface. Hornblende alteration occured after some of the andesine had crystallized, for where small hornblende crystals are included in the andesine, they remain unaltered, whereas unprotected hornblende crystals in the same rock were subjected to considerable deuteric alteration.

The Mg, Ca, Al and Si content of these deuterically altered hornblende crystals was in parts wholly, elsewhere partially abstracted during the process of alteration. The iron content was precipitated as abundant grains of magnetite, sometimes as fringes forming the bulk of the reaction coronas, sometimes distributed throughout the original hornblende crystals to form pseudomorphs of magnetite.

The greater stability of the augite throughout the phases of hornblende alteration enabled it to withstand attack by surging volatile components during (and subsequently to) effusion. Only rarely does the augite show evidence of narrow reaction borders developing.

Rapid crystallization of the residual molten portions of the various fractions of the andesitic magma, in positions near the earth's surface, led to the formation of a glassy groundmass in many and a crypto-crystalline to micro-crystalline groundmass in a few of the andesitic rocks.

Especially in the basalts (which were more vesicular than andesites at Aitape), but also to some extent in the andesites, subsequent alteration of solidified portions of the lavas by hydrothermal (possibly juvenile) solutions, led to selective mineral replacement and ultimate precipitation of newly formed products such as opal, crypto-crystalline silica, crystalline silica, calcite and delessite. The porphyritic augite-hypersthene andesite on Tumleo Island and the pyribole andesite at Tepier Plantation west of Aitape on the mainland, show no effects of this phase of alteration of the andesitic lavas, (c.f. table IV), even hornblende remaining unaltered. This, and the fact that field evidence indicates that porphyritic augite-hypersthene andesite was the last volcanic rock emitted in this area, all point to a cessation of the evolution of active hydrothermal waters in these parts, and consequently, cessation of selective mineral replacement, some time prior to the final emission of solid volcanic products in the Aitape district.

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THE IDENTITY OF SPADELLA MORETONENSIS JOHNSTON AND TAYLOR.

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The benthic genus *Spadella* is not so well known as the more pelagic chaetognaths. The first record of the genus in Australia was the description by Johnston and Taylor (1919) of *Spadella moretonensis* from a single preserved specimen collected at low water mark at Caloundra, Moreton Bay. Mawson (1944) recorded three species of the genus, two of them new, from material dredged in water from 70 to 100 metres deep off the southern New South Wales coast. Thomson (1947) recorded *Spadella cephaloptera* (Busch) from one specimen taken in a vertical plankton haul in 20 metres inshore off Port Hacking.

Recently specimens of a species of *Spadella* were found to be abundant amongst the eel-grass (*Zostera marina*) in various parts of Moreton Bay, including the type locality of *Spadella moretonensis*. The species is very common on the mud-flats at Dunwich, Stradbroke Island. Specimens were kept alive for some time in aquarium jars enabling a more detailed inspection of the animals than was possible for Johnston and Taylor. The species was determined to be *Spadella cephaloptera* (Busch) 1851.

The measurements of 60 specimens are summarised in the following table:—

Length mm.	Tail %	Hooks no.	Ant. teeth no.	Post teeth no.	Maturity stages.			
					IV.	III.	II.	I.
					%	%	%	%
6–7	52–55	9–10	3–5	0–1	100			
5–6	50–54	8–10	2–4	0–1	20	80		
4–5	50–54	7–9	2–4	0–1		10	80	10
3–4	50–53	7–9	2–4	0–1			20	80
2–3	50–52	7–8	2–3	0–0				100

The maturity stages are distinguished as in Thomson (1947).

Specimens are short and robust. There is one pair of lateral fins the membranes of which pass around the seminal vesicles to merge with those of the tail fin. Anterior origin of lateral fins varies from a little in front of the receptaculum seminis on trunk segment to immediately behind lateral insertions of transverse septum. This level is anterior to anus which is anterior to the median portion of transverse septum and posterior to lateral insertions (figure 1). Both lateral and tail fins are rayed except for membranes which pass around the seminal vesicles. Tail fin spatulate rather than broadly rounded as in pelagic chaetognaths.

Hooks 7 to 10., anterior teeth 2 to 5; posterior teeth usually absent. Hooks or seizing jaws slender, with shaft bearing a spiral pattern, cutting edge smooth, point of hook sharp. Point inserted rather less than a quarter of its length into shaft. Anterior teeth rather long, slender and twisted. Posterior teeth when present, short and squat.

Corona ciliata somewhat variably shaped but always situated in neck region. Usually oval in shape with long axis transverse to long axis of body. Posterior margin of corona generally hollowed inwards.

Collarette well defined, commencing at anterior end of head; widest and most prominent in neck region, but extending to the receptula. Smaller specimens have a pair of prominent tentacles laterally on head at about level of eyes. These tentacles are not readily seen as they can be folded into slight grooves on the head. A pad of minute papillae is present antero-laterally each side of mouth.

Ovaries extend about two-thirds of length of trunk. In ripe condition, 3 to 10 large eggs are apparent. Seminal vesicles and receptula reniform in shape. Ventral transverse musculature present throughout trunk, prominent anteriorly.

As Yosii and Tokioka (1939) reported for Japanese specimens, the number of posterior teeth is fewer than that recorded for European specimens. This seems to be a common feature of several species which are present both in the Atlantic and the Pacific Oceans (see Johnston and Taylor (1919), Tokioka (1940) and Thomson (1947)). This difference cannot be accounted as having specific value. The complete absence of posterior teeth has not been recorded for European specimens, except by Moltschanoff (1909) for his *Spadella parvula.* John (1933) figured and mentioned in the text only one row (the anterior) in his description of specimens from the Plymouth region.

The spiral pattern of the shaft of the hooks has been recorded by Yosii and Tokioka (1939), but has not been mentioned by observers of Atlantic Ocean specimens. The short denticles on the cutting edge of the hooks reported by Ritter-Zahony (1911) are not apparent in the Moreton Bay specimens. Both John (1933) and Yosii and Tokioka (1939) record the cutting edge as smooth and sharp.

According to Ritter-Zahony (1911) the anterior teeth are long, slender and twisted along their length as described here. Yosii and Tokioka do not comment on this point, but their figure shows this condition. On the other hand, John (1933) in his detailed study of the species stated that the teeth are small, conical structures with pointed tips. Possibly this is a matter of terminology or of experience with the phylum, for John's figures show the teeth as relatively large for a chaetognath.

In life, the transverse septum between trunk and tail is directed posteriorly in the median line so that the anus opens posterior to the lateral insertions of the septum. However, in preserved specimens the gut appears to contract and the septum apparently is carried forward to the position figured by Johnston and Taylor (1919) and Yosii and Tokioka (1939). This may account for the doubt as to whether the lateral fins commence anterior to the tail segment, although in the many specimens examined from Moreton Bay the origin is variable. The collarette merges into the anterior end of the fin, making the rays difficult to detect. However, of the 60 specimens examined, 21 had the lateral fins commencing in front of the receptula seminis on the trunk segment, whereas in 39, these fins commenced on the tail segment immediately posterior to the septum. Where the insertion is anterior to the septum, this small, anterior portion does not flare more widely as in *Spadella schizoptera.*

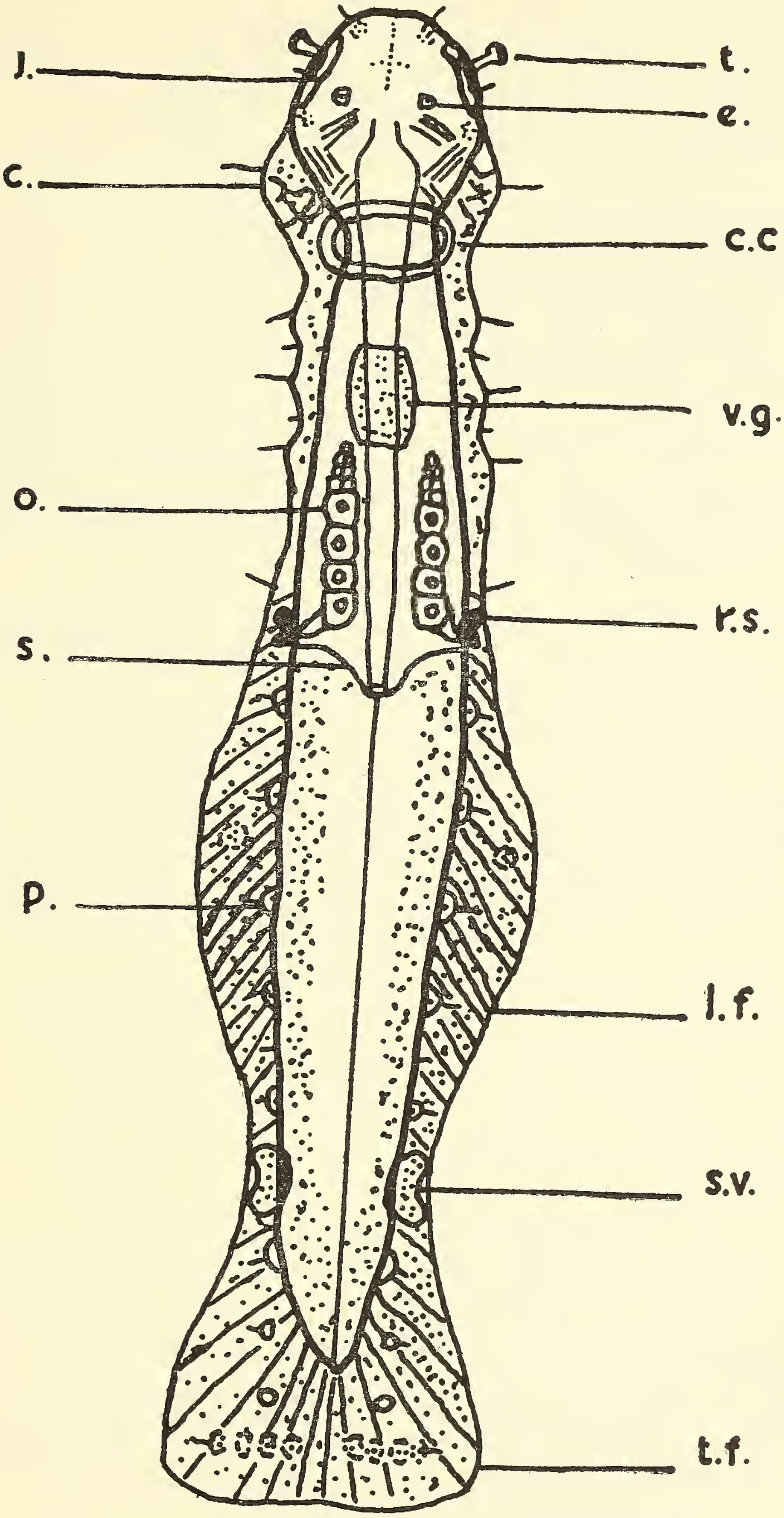

Figure 1. *Spadella cephaloptera.* Dorsal view.

a. anus; c. collarette; c.c. corona ciliata; e. eye; j. hooks; l.f. lateral fin; o. ovary; p. sensory papilla; r.s. receptaculum seminis; s. trunk-tail septum; s.v. seminal vesicle; t. tentacle; t.f. tail fin.

The distribution of the collarette is identical in Moreton Bay specimens with European examples. Johnston and Taylor (1919) were apparently misled by the remarks of Ritter-Zahony (1911a) "Collerette schon vor dem Halse beginnend, am breitesten in der Gegend der Corona, dann rasch sich verschmälernd, aber bis an die Mündung der Receptacula, also fast über den ganzen Rumpf reichend." However, in Ritter-Zahony's terminology "Rumpf" means the trunk segment, not the whole body.

The distinction made by Johnston and Taylor (1919) between the corona shape of *Spadella cephaloptera* and *S. moretonensis* is not of any significance because of the great variability in the outline of this structure. This has been commented on previously by John (1933) and Yosii and Tokioka (1939). Giard (1874) and Johnston and Taylor (1919) were in error in suggesting that the lateral tentacles reported by previous observers were foreign organisms. All specimens under 3·5 mm. bear them. John (1933) stated that they can be found in larger specimens retracted alongside the head, but careful examination has failed to reveal them. No specimen over 5 mm. in length was found to bear them.

Johnston and Taylor (1919) are probably in error in stating that transverse muscles occur in the tail in *moretonensis.* Their diagnosis was based on a solitary specimen, and there is no evidence from their text or figures that it was sectioned. It is most difficult to determine the presence of transverse muscle from external appearances. The longitudinal muscles are transversely striated and the contraction of the longitudinal band in the tail segment may cause superficial transverse striations which have the appearance of transverse muscle in external view (Yosii and Tokioka). Sectioning of Moreton Bay specimens failed to reveal transverse musculature in the tail.

The Moreton Bay specimens adhere to the surfaces upon which they rest by means of the adhesive papillae described by John. There are no glands associated with the papillae; the adhesion is entirely mechanical by the muscular creation of partial vacuua in the pits between the papillae. According to John (1933), the adhesive papillae occur only on the anterior third of the tail segment of adult *cephaloptera,* but in the newly hatched larvae they are said to occur only on the trunk and the head. The Moreton Bay specimens had adhesive papillae on at least the posterior third of the trunk segment as well as on the tail. Ritter-Zahony (1911, 1911a) and Kuhl (1938) both say merely that adhesive papillae occur on the ventral epitheleum without designating the limits of the adhesive area. Yosii and Tokioka (1939) were in error in considering the two club-shaped bodies found by Johnston and Taylor on the ventral surface of the posterior part of the tail as adhesive organs. Most probably they would be foreign bodies as suggested by Johnston and Taylor.

The lack of any clear difference between the specimens from Moreton Bay and the descriptions of *S. cephaloptera* from the north Pacific and the Atlantic Oceans leads to the conclusion that *Spadella moretonensis* Johnston and Taylor is a synonym of *Spadella cephaloptera* (Busch).

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TWO NEW SPECIES OF DIPETALONEMA (NEMATODA, FILARIOIDEA) FROM AUSTRALIAN MARSUPIALS.

By M. J. MACKERRAS, Queensland Institute of Medical Research, Brisbane.

(With Plate I. and nine Text-figures.)

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INTRODUCTION.

Many filariid worms have already been described from Australasian marsupials, by Leidy (1875), von Linstow (1897, 1898, 1905), Breinl (1913), Solomon (1933), Baylis (1934) and Johnston and Mawson (1938a, 1938b). It was therefore rather surprising to find a previously undescribed species in the common bandicoot, *Isoodon obesulus* Shaw and Nodder, and another in the red-legged wallaby, *Thylogale wilcoxi* (McCoy).

The taxonomy of this group of parasites is in an unsettled state. Yorke and Mapleston (1926) founded a genus *Breinlia* for the species which occurs in the possum, *Trichosurus vulpecula,* and which was originally described as *Filaria trichosuri* by Breinl (1913). Solomon (1933) placed the species from the tree kangaroo in this genus, but later workers, including Baylis, Johnston and Mawson, and Chabaud (1952) have regarded *Breinlia* as a synonym of *Dipetalonema* Diesing, and for some years all the species from Australasian marsupials have been assigned to this latter genus. The species described here have therefore also been placed in *Dipetalonema,* though with some reservation, because the writer feels that the genus *Breinlia* may well be revived in the future. Nothing, however, is yet known of the life histories of these parasites. When some of these are elucidated, it may be possible to group the species into natural assemblages.

DIPETALONEMA JOHNSTONI n. sp.

The adult worms were found loosely coiled in the subcutaneous tissue of the anterior abdominal wall of the short-nosed bandicoot, *Isoodon obesulus.* An examination of 33 individuals from various localities in South Queensland showed six to be infected. The infected individuals came from Mount Nebo and Mount Tamborine. Some female specimens collected by Mr. R. Riek from the long-nosed bandicoot, *Perameles nasuta,* also belong to this species. Usually there were from 2 to 10 adult worms present; one individual, however, had a heavier infection, about 25 worms being removed.

TYPES.—Holotype male, allotype female and a skin section showing microfilariae have been deposited in the Queensland Museum.

DISTINCTIVE FEATURES.—Very short and slender; oesophagus uniform in width, vulva immedidately post-oesophageal; tail ending in four digitations; long spicule complex, short one relatively simple; no gubernaculum.

Male.—Capillary in form, 20-32 mm. long by 0·14 mm. in maximum breadth. The cuticle is relatively thick and smooth except in the posterior part of the body, where fine transverse striations appear. These striae are most clearly defined in the spiral portion of the tail. Each stria is ornamented with a row of minute, close-set, regular bosses. Striae and bosses fade out in the cloacal region. The head measures 0·12 mm. in diameter and is followed by a distinct neck, 0·1 mm. in diameter. No cephalic papillae nor oral chitinous structures could be detected. The nerve ring lies about 0·28 mm. from the anterior end. The oesophagus measures 0·7 to 0·9 mm. in length by 0·025 to 0·03 mm. in diameter. It may widen slightly from before backward, but there is no definite division into two parts. The posterior end of the body is coiled into a tight spiral of three or four turns. The tail measures 0·14 mm. from tip to cloaca, and ends in four minute digitations (Text-fig. 2).

The left spicule is long and slender, measuring 0·35 mm. in length by 0·012 mm. in maximum breadth, which is at the proximal end. It consists of a stiff, tubular, proximal portion about 0·18 mm. long, which appears irregularly chitinised or roughened. There is then a more flexible-looking part supported by two slender struts, which seem to merge together to form the curved, needle-like distal portion (Plate 1, fig. 3; text-fig. 2). The smaller, right spicule is 0·080 mm. long by 0·010 mm. wide; it is boat-shaped with the keel directed dorsally. The distal end is bluntly spatulate. The ventral surface appears to be grooved to accommodate the long spicule. There is no gubernaculum. The cloacal papillae consist of two pairs of small pre-anals, two pairs of minute ad-anals and two pairs of post-anals. (These papillae are only shown on one side in text-fig. 2.)

Female.—Considerably larger than the male, measuring 45 to 70 mm. in length by 0·2 to 0·3 mm. in maximum breadth. The cuticle is similar to that of the male, except that bosses are inconspicuous or absent. The shape of the head and form of oesophagus are similar to those in the male. The oesophagus measures 0·7 to 1·1 mm. in length by 0·03 to 0·04 mm. in width. In some specimens the anus is ill-defined and may not be patent. The ovarian tubes begin in the posterior part of the body. The uteri are packed with well-developed embryos. The uteri pass forward to a point about 2 to 3 mm. from the anterior end, where they unite to form the vagina. This is a muscular tube about 1 mm. in length; it leads through a muscular bulb to the vulva, which opens in the immediate post-oesophageal region about 1·1 to 1·5 mm. from the anterior end. There is a distinct bulge at this point; opisthodelphys (Text-fig. 1). The tail ends in four digitations as in the male. A pair of minute subterminal papillae was detected in some specimens. The length from anus to tip of tail is 0·145 mm.

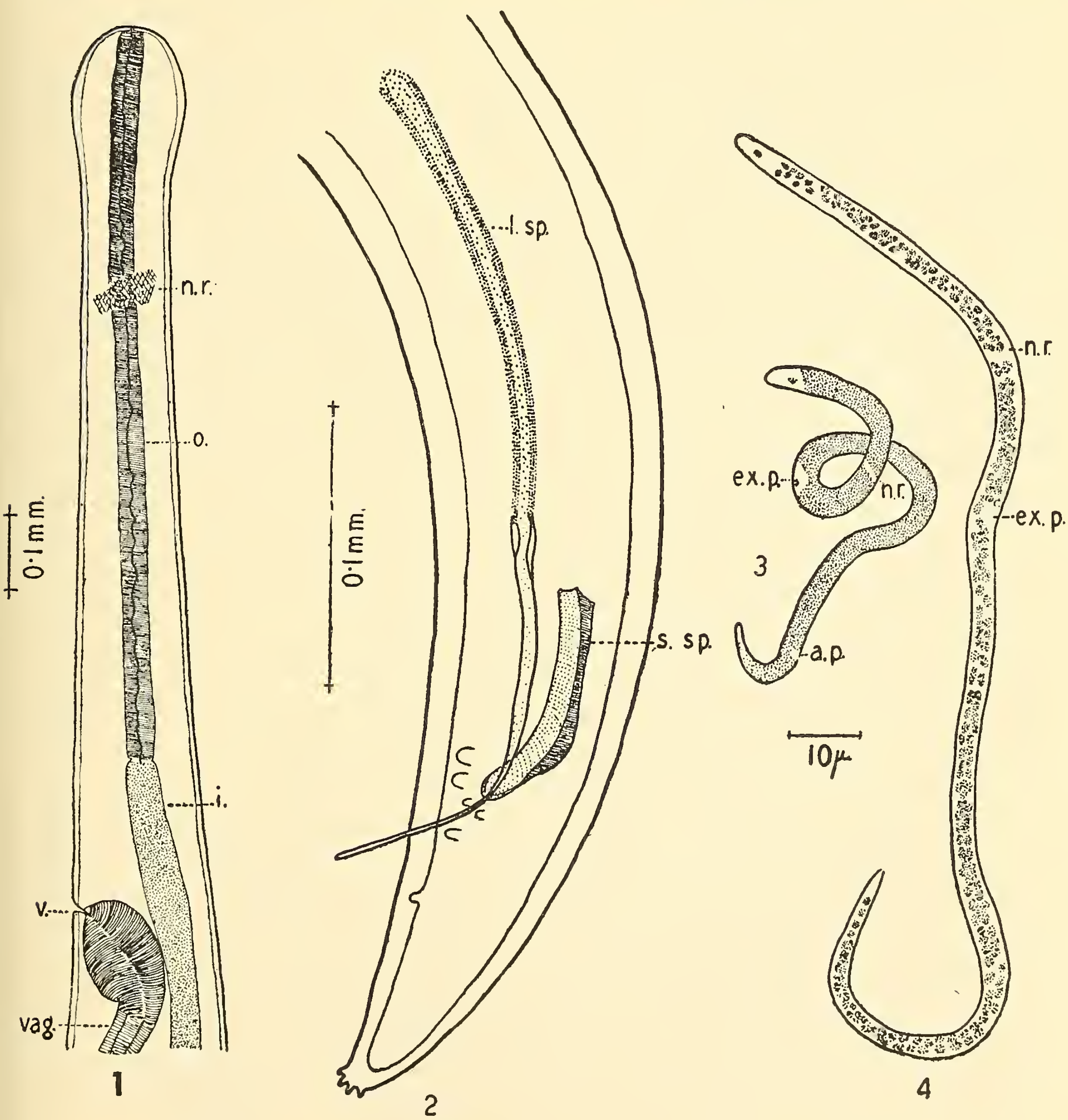
Microfilaria.—These were not detected in blood films, but in sections of the skin they were regularly found lying immediately below the Malpighian layer (Plate 1, figs. 1 and 2).

Specimens from the uterus of the female measure 0·110 mm. to 0·120 mm. by 0·004 mm. The head is blunt, with two refractile spots in Leishman-stained smears. The tail is pointed. The nerve ring is 0·025 to 0·03 mm. and the excretory pore 0·04 to 0·045 mm. from the anterior end. No sheath was detected (Text-fig. 3). Specimens found in thick, tangential sections of the skin are considerably longer.

Two perfect specimens measure 0·19 and 0·2 mm. in length respectively, by 0·004 to 0·005 mm. in width. The head is blunt; no refractile spots were detected. The nerve ring lies 0·045 to 0·05 mm. and the excretory pore 0·075 mm. from the anterior end. The anal pore was not defined (Text-fig. 4).

Microfilariae have only been found in skin sections of those animals which harboured the adult worms, and it is assumed they originated from them. The differences in measurement may be due partly to shrinkage in a dried film, but it seems likely that some growth had also occurred. The positions of the nerve ring and excretory pore are the same proportionally as in those from the uterus.

Taxonomic Notes.—The tip of the tail seems quite characteristic, no other species being recorded with four terminal digitations. It differs in size (being much smaller) from all the described species except *D. rarum* Johnston and Mawson, which is known only from the female, *D. dasyuri* Johnston and Mawson, and *D. capilliforme*



Text-figs. 1-4. *Dipetalonema johnstoni* n. sp.: fig. 1, anterior end of female; fig. 2, posterior end of male in ventro-lateral view; fig. 3, microfilaria from uterus; fig. 4, microfilaria from skin; a.p., anal pore; ex.p. excretory pore; i. intestine; l.sp., long spicule; n.r., nerve ring; o., oesophagus; s.sp., short spicule; v. vulva; vag. vagina.

Baylis. In *rarum* the head bears four papillae and the tail two subterminal papillae; the vulva is further back (3·55 mm.) than in *johnstoni* n. sp. (1·1 mm.). In *dasyuri* the vulva is very much further back, being 6 mm. from the anterior end; moreover, the spicules in *dasyuri* are short and nearly equal. In *capilliforme* the females are usually larger, about 140 mm. by 0·3 mm., than in *johnstoni* n. sp. (about 50 mm. by 0·2 mm.), but the oesophagus is shorter and the vulva nearer the anterior end.

I have named this species in honour of the eminent Australian parasitologist, the late Professor T. Harvey Johnston of Adelaide.

DIPETALONEMA THYLOGALI n.sp.

The adult worms were found in the peritoneal and pleural cavities of a red-legged wallaby, *Thylogale wilcoxi,* from Tamborine, South Queensland.

Types.—Holotype male and allotype female have been deposited in the Queensland Museum.

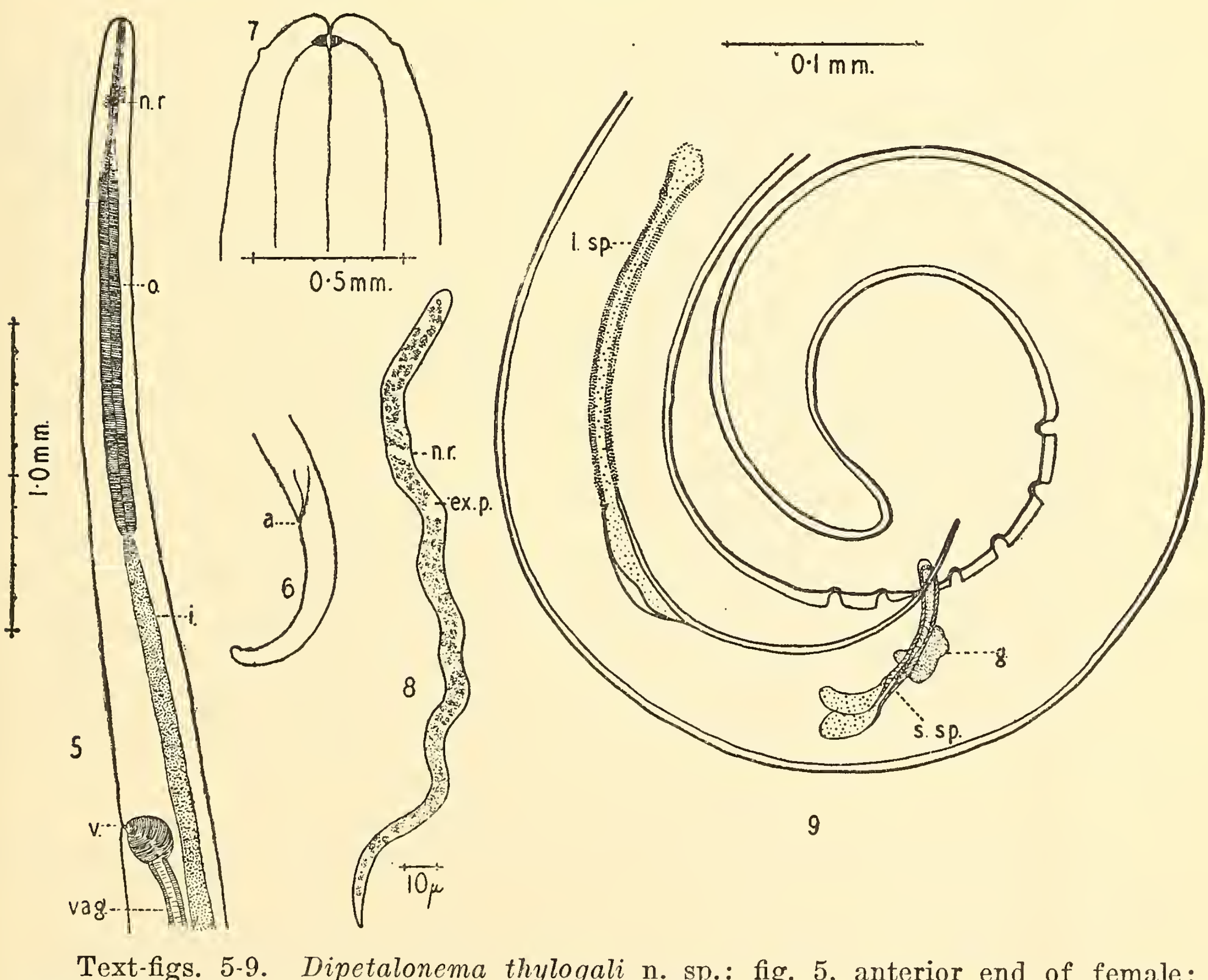
Distinctive Features.—Relatively short, slender worms; cephalic papillae well-developed; with a chitinous ring at the base of the buccal cavity; cuticle transversely striated; oesophagus distinctly divided into two parts, vulva post-oesophageal; tail bluntly rounded; long spicule complex, short one relatively simple; gubernaculum present.

Male.—A single specimen found in the mesentery measured 37 mm. long by 0·2 mm. in maximum breadth. The cuticle is smooth anteriorly, but fine striations appear in the mid-oesophageal region. They are more pronounced in the middle of the body, appearing as regular lines 0·005 mm. apart. Some irregular, minute, elongate bosses are associated with the striae, and are best defined in the spiral region of the posterior end. Both striae and bosses fade out in the cloacal region. There is no neck, the width of the head end increasing gradually from before backward. There is an outer circle of four, moderately large, cephalic papillae, and an inner circle of smaller ones, difficult to count. A chitinous ring is present at the base of the minute buccal cavity. The oesophagus consists of a narrow anterior portion, 0·44 mm. long by 0·03 mm. wide, and a longer, broader posterior section, which is 1·2 mm. long by 0·05 mm. wide. The nerve ring is about 0·21 mm. from the anterior end. The posterior part of the body is coiled in a loose spiral of three turns. The bluntly rounded tail measures 0·45 mm. from tip to cloaca.

The left spicule is 0·45 mm. long. It consists of a stiff, tubular proximal portion 0·2 mm. long by 0·02 mm. in maximum diameter, a shorter, more flexible-looking portion supported by two strong, marginal struts, and a curved, needle-like distal portion about 0·19 mm. long. The right spicule is 0·11 mm. long. The proximal end is expanded into two lobes which are less heavily chitinised than the remainder. The distal end is rounded, spatulate. There is a small, rectangular gubernaculum, 0·03 mm. in length, which is grooved on the ventral aspect to accommodate the small spicule, which in turn appears to support the long spicule (Text-fig. 9; plate 1, fig. 4). The cloacal papillae are large; there are two pairs of pre-anal, one pair of ad-anal (not shown in diagram) and four pairs of post-anal papillae, the last pair being asymmetrically placed.

FEMALE.—One intact and one broken specimen were studied. Length 98 and 94 mm. by 0·45 mm. in maximum diameter. The cuticle resembles that of the male, except that bosses are ill-defined or absent. The head and conformation of the oesophagus resemble those of the male. The anterior part of the oesophagus is 0·45 mm. by 0·03 mm., and the posterior part 1·4 mm. by 0·07 mm. in width. The anus is clearly patent. The nerve ring lies between 0·2 and 0·3 mm. from the anterior end. The ovarian tubes begin in the posterior part of the body. The uteri contain microfilariae, and pass forward side by side to within 4 or 5 mm. of the anterior end, where they unite to form the vagina. This is thrown into coils before opening to the exterior through a muscular bulb. The vulva is in the post-oesophageal region, 2·8 mm. from the anterior end; opisthodelphys. The length of the tail from tip to anus is 0·55 mm. (Text-figs. 5 and 6).

MICROFILARIA.—Scanty microfilariae were found in smears taken from blood clot around the heart. It should be noted that the lungs, diaphragm and liver had been removed from the wallaby in the search for hydatid cysts before the carcase was examined for filariae. At least one mature female worm had been damaged, so that the presence of microfilariae in blood films may have been an artefact. They were not, however, found in skin sections. Measurements in Leishman-stained films were:—Length 0·210 to 0·245 mm. by 0·007 to 0·008 mm. in width. The head is rounded and the tail pointed. The nerve ring is 0·05 to 0·06 mm. and the excretory pore 0·075 mm. from the anterior end. The anal pore was not defined.



Text-figs. 5-9. *Dipetalonema thylogali* n. sp.: fig. 5, anterior end of female; fig. 6, posterior end of female; fig. 7, head of female; fig. 8, microfilaria from blood; fig. 9, tail of male. Figs. 5 and 6 are to the same scale. a., anus; ex. p., excretory pore; g., gubernaculum; i., intestine; l. sp., long spicule; o., oesophagus; s. sp., short spicule; v., vulva; vag., vagina.

Taxonomic Notes.—This species appears to be nearly related to *D. robertsi* Johnston and Mawson, but may be distinguished by its smaller size; by the position of the vulva, 2·8 mm. from the anterior end in *thylogali* n. sp., 6·5 mm. in *robertsi*; by the smooth tail, subterminal papillae present in *robertsi*; by the greater length of the long spicule and the greater disproportion of the two spicules, left four times length of the right in *thylogali* n. sp., only twice length in *robertsi*.

ACKNOWLEDGEMENTS.

I wish to thank Mr. T. Lawton of Mount Nebo for several infected bandicoots, and Mr. R. Riek for the wallaby, two infected bandicoots and for material from other marsupials. I am indebted to Mr. G. Mack, Queensland Museum, for identifying the marsupials.

SUMMARY.

Two new filariid parasites are described from marsupials from South Queensland. *Dipetalonema johnstoni* n. sp. is described from the subcutaneous tissue of the bandicoots, *Isoodon obesulus* and *Perameles nasuta*; and *Dipetalonema thylogali* n. sp. from the body cavity of the red-legged wallaby, *Thylogale wilcoxi*.

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EXPLANATION OF PLATE I.

Dipetalonema johnstoni n. sp.—Fig. 1, vertical section of skin of bandicoot showing microfilariae, x 192; fig. 2, high power view of another field, x 650; fig. 3, posterior end of male.

D. thylogali n. sp.—Fig. 4, posterior end of male. g., gubernaculum; p. l. sp., proximal part of long spicule; s. sp., short spicule; t. l. sp., tip of long spicule.

(Figs. 3 and 4 are at the same magnification; the small divisions in the scale equal 0·01 mm.)

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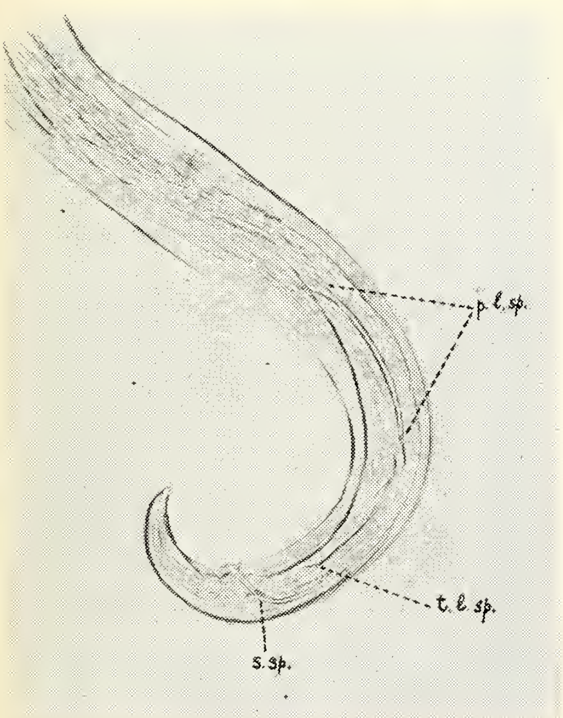

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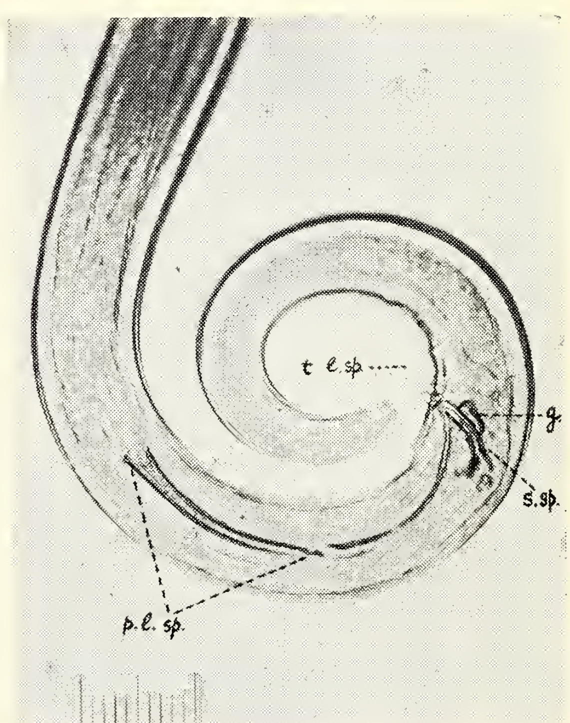

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Vol. LXIV., No. 5.

MEMORIAL LECTURE.

PROFESSOR T. HARVEY JOHNSTON: FIRST PROFESSOR OF BIOLOGY IN THE UNIVERSITY OF QUEENSLAND.

By Dorothea F. Sandars, Queensland Institute of Medical Research and Department of Social and Tropical Medicine, University of Queensland.

(With Plate II.)

(*Delivered before the Royal Society of Queensland, 1st December,* 1952.)

On 30th August, 1951, many of us, listening to the 7 p.m. National News were shocked by the following announcement:—

> "The death occurred in Adelaide this morning of Professor Thomas Harvey Johnston, Professor of Zoology at Adelaide University.
>
> "Professor Johnston was one of the best known biologists in Australia. He had won many high scientific awards for his research work, particularly on parasites.
>
> "Professor Johnston was Chairman of the Queensland Prickly Pear Commission from 1912 to 1914; Chief Biologist on the British, Australian and New Zealand Antarctic Research Expeditions from 1929 to 1931; and the author of more than 250 publications about Australian zoology. He was 69."

So it was that Australia learnt of the loss that day of her senior Professor of Zoology, so the world was told that there had passed one of its leading parasitologists, and to many of us there came a deep hurt in the realization that we had lost, not only a sound adviser and ready fount of knowledge, but a very sincere friend.

Thomas Harvey Johnston was born in Sydney on 9th December, 1881. Of his ancestry I have discovered little, but one thing has stood out in the minds of several of us, and that is his pride in claiming forebears who had come from the north of Ireland. Harvey Johnston was apparently a hard-working small boy at school, and grew to become a very studious young man, whose career was marked by one distinction after another. Matriculating at 15 years of age, he joined the New South Wales Education Department, and winning the Jones Memorial Scholarship, proceeded to the University. In 1902, Thomas Harvey Johnston commenced his University career at the University of Sydney—a career that was to claim him for the rest of his life. First he completed a Bachelor of Arts degree, and in the last year of this course, while studying English III., he did the first year requirements of a Science Degree. In 1906 he completed the requirements for his Bachelor of Science degree, gaining second class honours in Biology. During the same year he successfully presented a thesis in Modern History on "The Puritan Period" for a Master of Arts degree. Thomas Harvey Johnston had the degree of Bachelor of Arts conferred on him on 6th May, 1905; and at the same ceremony on 27th April, 1907, both the degrees of Bachelor of Science and Master of Arts. This in itself seems no small task, but add the fact that from 1903-6 he was teaching at the Fort Street High School and we see that here must have been a young man with determination, enthusiasm and tireless energy—and yet with enough spare time to woo and win for himself Miss Alice Maude Pearce, whom he married on 1st January, 1907.

Along with other students, many of whom became well known, Harvey Johnston received a very thorough training in Zoology under the famous Professor W. A. Haswell. Even as early in his career as this, Johnston was renowned for being a stickler for details, and was always regarded as being the one of the group who could invariably "produce the facts." A slim, serious and keen young man, he was not, however, without a certain amount of fun, and very often in the Zoology laboratory, when some innocent practical joke was discovered, the comment would be heard, "another of Harvey's tricks!"

In 1907-8 he was a Lecturer in Zoology and Physiology at the Sydney Technical College, where he added to his academic achievements by becoming, in 1908, an Associate (in Biology and Agriculture), and in 1910 a Fellow. In 1908 he was also the Assistant Director of the Bathurst Technical College, New South Wales. In 1909, on the establishment of the Bureau of Microbiology in Sydney, Johnston was appointed an Assistant Microbiologist to Dr. J. B. Cleland. These years at the Bureau were both productive and stimulating, and were to have a marked effect on the young man, which persisted throughout his subsequent career in Queensland, and probably to a degree throughout his later lifetime. Papers on parasitic Protozoa and Helminths flowed from his pen; papers written both by himself alone and jointly with Cleland. To workers to-day, this rate of production is alarming, but it must be remembered that here was a young and vigorous team working in an almost untouched field. The Bureau was newly established, and the young man was being pushed continually to produce paper after paper; publications were demanded of him, and he gave—but very often he expressed the opinion that he did not have enough time to complete papers in the manner that he would have liked. That sense of thoroughness, so characteristic of him throughout his life, rebelled against this rapid churning out of work.

Of the association with Dr. J. B. Cleland at the Bureau I can do no better than to quote directly what Cleland himself recently wrote to me of the period: "Our association there and again later in Adelaide was a very happy one. Harvey Johnston had already shown considerable interest in Parasitology, especially in the Cestodes. As I had a very catholic interest in natural history and the scope of activities of the new Bureau was very wide, we began to follow up the parasites of our Australian mammals, birds, batrachians and fishes. The birds were collected under licence and every possible use made of these victims of scientific curiosity. The colours of the soft parts were noted, the temperatures sometimes taken, measurements made, blood smears prepared, feathers searched for Mallophaga, intestines examined for worms and even in some cases the carcase was not thrown away. I remember my wife being given the remnants of a wonga or other pigeon, which had gone through such an overhauling, for a meal. The blood smears were stained and searched for Haematozoa and the results of our researches published in the journals of the Linnean Society of New South Wales or the Royal Society of New South Wales. In examining these blood smears we noticed that the size of avian red cells varied considerably, being larger in the more archaic families than in the Insessores; in blood smears from fishes, the sharks, &c., had larger cells than the bony fishes, and seemed to lead on to the red cells of reptiles and then to those of birds. Ceratodus had far and away the largest red cells. We collected material wherever we went. On one trip to Kurnell on Botany Bay, we went as far as to try cooking and eating the flesh of a Varanus after searching it for ticks, cestodes, &c.''

This habit of not wasting the flesh of an animal investigated for parasites persisted throughout Johnston's lifetime; one of his later students remembers, even as recently as 1948, that ''It was Christmas eve and the 'Prof.' had been examining a duck for parasites, then carefully he wrapped up the body and took it home.'' Professor Cleland also referred to the contact they had had with Queensland's Dr. T. L. Bancroft who, again to use Cleland's own words, ''was very helpful to us, generously placing at our disposal blood smears and parasites from birds, mammals and reptiles that he had collected in Eidsvold.''

Meanwhile, this energetic young zoologist, besides producing some twenty-five publications and part of the reports of the Bureau, had, during 1909-10, found time to write a thesis on the cestodes, the group of helminths that was essentially his greatest love throughout his life. This thesis, ''Studies in Australian Cestoda,'' and an examination for which he sat, gained for him a Doctorate of Science of the University of Sydney, to which degree he was admitted on 1st May, 1911. The thesis was subsequently published in *Records of the Australian Museum,* 1912, under the title ''On a re-examination of the types of Krefft's species of Cestoda in the Australian Museum, Sydney.'' Johnston's papers for this period are mainly to be found in the journals of the Royal Society of New South Wales of which he became a member in 1909, making five contributions in that one year, and the Linnean Society of New South Wales, of which he became a member in 1907. Many of these were on the blood parasites of native animals, particularly fishes, reptiles and birds. And still he found time during these years to indulge in outside activities, acting as chief examiner for an ambulance branch and for the Royal Life Saving Club.

On the establishment of the University of Queensland, Dr. Harvey Johnston was one of the early appointees on the staff, being made Lecturer-in-Charge of the Department of Biology. He could not take up his appointment until June, 1911, the teaching within the newly-formed department being done by Dr. Hamlyn-Harris. Of the arrival of Dr. Johnston and his family in Brisbane, Dr. C. D. Gillies, one of Queensland's first students in Biology, has recalled the following:—

> ''It was about the middle of 1911 when Raymond Dart and I called at 'Menzies,' George Street, to meet the Johnston family. Fortunately, we found them in. Dr. and Mrs. Johnston were a very pleasant, friendly couple, with two very healthy looking small children of the romper stage. Johnston was a slender man of medium height, obviously a student of some

academic subject, very earnest, serious and full of enthusiasm. At that time he had just been appointed to the lectureship in Biology; the Professorship came later."

The Biology Department was initially housed in what is now the administration building of the University, in the rooms on the left on entering the Main Hall. Teaching facilities were those of an embryonic department, the blackboard was easel-type, the laboratory bench space was improvised by having tables with holes cut along the middle to allow slop buckets to be inset, and no water was laid on. It is perhaps of interest to note that for the year 1911 the maintenance of the Biology Department was £18 16s. 2d. The rest of the staff for Biology was nominated as "One Laboratory Attendant (Boy)."

Those early years some of you will recall—my story is one pieced together from memories of others. Again Dr. Gillies has recalled the following of Dr. Johnston:—

> "It was soon obvious that (*a*) he wanted us to understand and fully appreciate his remarks, as he spoke slowly and very distinctly to enable us to take down what he was saying, (*b*) he was an enthusiastic man and did his best to impart some of his enthusiasm to us. Johnston lectured down to the level of the average student and didn't parade his knowledge per medium of vague but sonorous oratory. He made us realise that Biology was essentially a practical study, so we had to handle as many specimens as we could both in the laboratory and in the field. He lavishly illustrated his remarks with simple diagrams, frequently with the various systems contrasted in vivid colours."

Excursions became an essential part of the Biology curriculum, and it was soon an established custom that a week in May was spent at Caloundra and a fortnight in August somewhere further north, usually on the Great Barrier Reef on Masthead Island, North-West Island, &c. The organisation of any of these excursions, especially in the days before modern transport, was no small matter. However, Dr. Johnston always had everything arranged right to the last detail. To go to Caloundra was more or less an adventure, first by train to Landsborough, and then by coach or a high-wheeled motor carriage to the township; on some occasions Caloundra was approached by the Koopa to Bribie Island and the trip completed by hired launch from which dredging could be done. Mrs. Johnston and their two small children, a girl and a boy, always accompanied these excursions.

Meanwhile this young zoologist was receiving outside recognition, being made a Fellow of the Linnean Society of London on 7th December, 1911, and a Fellow of the Royal Microscopical Society on 17th January, 1912. Then there came the opportunity that was to establish his name permanently in the biological world. In September, 1912, he was appointed Chairman of the Commission of Inquiry, with Mr. Henry Tryon, to investigate means of control of the spread of the introduced pest, prickly-pear, which had become an economic problem. In 1912-14 they went on a world trip to undertake the necessary investigation, and I am sure that there is much we do not know that could be told of these two travellers. It is certainly recognised that they did not fit easily into each other's ways, and apparently even to-day in America, Johnston and Tryon are still remembered as the "prickly pair." One result of this trip was the successful introduction of one species of cochineal insect, *Dactylopius ceylonicus,* for the control of one species of pear, *Opuntia monacantha.* It was this success which paved the way for the whole project to be regarded favourably. Meanwhile, a laboratory where chemical investigations were being carried out under the direction of Dr. Jean White, had been established at Yulacca, and all specimens from the Commission were forwarded to her. In 1914, Johnston and Tryon published an account of the investigations they had made on their world trip: "Report of the Queensland Prickly Pear Travelling Commission."

Johnston's interest in the Prickly Pear problem was not to wane until well after his establishment in Adelaide, and he produced numerous publications on the subject. He was appointed Controller of the Commonwealth Prickly Pear Laboratories, and went on a second world trip in 1920. He was seconded for this purpose until the end of 1922 first from the University of Queensland, and then from the University of Adelaide. The laboratory at Sherwood was established, and an intensive plan of investigation in biological control undertaken. In planning and guiding these researches it may perhaps be well said that Professor Johnston launched the ship for biological control of Prickly Pear, but as he himself said, before that ship came successfully home to port, he had retired from command. The eventual success of *Cactoblastis* and the control of Prickly Pear is common knowledge. Perhaps it is not as well known that *Cactoblastis cactorum* was actually introduced into Queensland by the Travelling Commission in 1914, found to feed readily on the pest pear, but unfortunately it died out. Again it was introduced from the Argentine in 1921, but again without success. (Johnston, Presidential Address: "The Australian Prickly Pear Problem," A.N.Z.A.A.S., 1923, p. 378.) It was in 1925 that this insect was at last successfully introduced with such dramatic results.

For the 1912-14 Prickly Pear world trip, Dr. Johnston had obtained leave of absence from the University of Queensland, provided he could find a replacement for himself, and preferably a man! This temporary appointment was accepted by a young Melbourne graduate, Miss Freda Bage. If Dr. Johnston had been responsible for nothing else, by being instrumental in bringing Miss Bage to Queensland he did the University of Queensland, the University Women's College and the State a very great service indeed.

Before he left, he had set the wheels in motion for a new departmental building, which was to have been between the tennis courts and the then Men's Common-room (to-day, the Department of Agriculture). He met Miss Bage in Sydney, sketched these plans for her, and gave her the impression, which he himself obviously must have had, that the buildings would be ready for occupation on her arrival. But not so; in point of fact that building was never erected. By some machination beyond the control of those who were to occupy and work in the new quarters, the small building he had designed "acquired wings," and transported itself to the top floor, above the Physics Department, in the new brick building which suddenly started to make its appearance. The original compact plan was simply stretched to fit the new, much larger, and differently proportioned space. The result was grotesque and impractical. But Miss Bage, in a very capable manner, took charge of the situation, wheedled the plans from the powers that were, and redesigned the available space, keeping as closely as possible to the original plans. On his return, Dr. Johnston appeared to be disappointed in the unexpected change, and probably never fully reconciled himself to the new building. To-day his touch can still be seen in the original part of the department—at the top of the stairs on the electricity switchboard, one switch still bears the label, "Dr. Harvey Johnston," and when I was in the department, those of his catalogues that were still in existence were in many ways the most reliable sources of information. He recorded everything, even the tools, and it is typical that the museum had both a card catalogue and a book catalogue!

In 1919, he received his professorship, being appointed as the first Professor of Biology in the University of Queensland. This position he retained until appointed to the Chair of Zoology in the University of Adelaide in August, 1921.

All this while, scientific research had been continuing, and papers were being published rapidly. As head of the new Biology Department, he was continually consulted on all manner of economic problems, such as sheep blowfly, cattle tick, or fish epidemics. Papers on all these were published, as well as continued work on his beloved helminths. Marine biology, and even many odd marine groups, also found their place in the list of work being done. From 1911 until 1923, in collaboration with many of his students, he published, in the *Proceedings of the Royal Society of Queensland* alone, some thirty papers. These all demonstrated his extremely wide range of biological knowledge. Early in his career he revealed a remarkable capacity for keeping his finger directly on the heart of every one of numerous diverse problems under investigation. This characteristic he retained until his death and thereby could maintain his wide zoological interest. He guided through to publication the work of many young students, and it is no doubt because of this, that we have inherited such a large legacy of papers by "T. H. J. and . . . " Altogether, he published alone, or with others, 299 papers. He kept a complete list of these, which has been published in the *Transactions of the Royal Society of South Australia,* volume 75, 1952.

During the period that he was in Queensland, there passed through the hands of Professor Johnston many students who were later to make their own mark, both in the scientific world and in other spheres. Mention may be made of a few only of the most outstanding of these: Professor R. A. Dart, late of the Department of Anatomy and Anthropology, University of Witwatersrand, South Africa; Professor O. W. Tiegs, F.R.S., Professor of Zoology in the University of Melbourne; Dr. M. J. Mackerras (née Bancroft), now of the Queensland Institute of Medical Research; Air Vice-Marshal Reginald Cassidy, R.A.F.; Dr. O. Hirschfeld, now Deputy-Chancellor of the University of Queensland, who is one of the many leading Brisbane medical men, too numerous to enumerate, who were taught by Professor Johnston.

In 1913, Dr. Johnston was awarded by the University of Melbourne the David Syme Memorial Prize and Medal for Research, and he was the first Walter and Eliza Hall Fellow in Economic Biology in the University of Queensland. Characteristically, he also developed interests outside his department; he was President of the Royal Society of Queensland in 1915-16, delivering an address: "A Census of the Endoparasites recorded as occurring in Queensland, arranged under their Hosts." He served as a Council member every year that he was in Brisbane, being Librarian for three years. As President of the Queensland Field Naturalists' Club for 1916-17, he delivered an address: "Ecological Notes on the Littoral Fauna and Flora of Caloundra, Queensland." This is a most important publication, and to-day it is still probably the best Queensland paper on marine ecology yet published.

In 1922, he was appointed to the Great Barrier Reef Committee, which had just come into being. He was one of the foundation members, being nominated as a representative of the University of Adelaide. Although a member until his death, he only attended one meeting, the third one of the Committee, on 3rd November, 1922.

In 1922, Mr. O. W. Tiegs, one of Johnston's leading Queensland students, went as his deputy to Adelaide until he himself could take up this new post. Tiegs stayed on for a further two years before proceeding to Melbourne, where he now occupies the Chair of Zoology. Apparently it took Johnston some time to settle into his new position; he was for a while seriously ill with pleurisy and had to take things easily. This new post meant working up once more a new department, but by now, perhaps, he knew what some of the pitfalls, some of the heart-aches attached to such a task, would be. Again, the Zoology Department was housed on the top floor of a three-storied building, the Darling Building, the bottom two floors housing the Department of Pathology, of which his old friend Professor J. B. Cleland was the head.

From this time onwards, Johnston's life seemed to acquire a greater degree of directiveness and serenity of purpose. He had a department within the University with a Medical School, and that had seemed to him, as a parasitologist, an important factor influencing his decision to apply for the Adelaide chair. Teaching and research grew and flourished under his direction, and there soon began to appear the steady stream of publications by which Professor T. Harvey Johnston will long be remembered. Year after year increasing classes of first and fourth year medical students, as well as science students and others, were instructed in the fundamentals of Zoology, made more interesting by a teacher who truly loved and lived his subject, and a teacher with an ever-increasing wealth of experience.

For many years he did most of the lecturing himself, and he was rarely known to escape immediately after a lecture, but was usually showered with a deluge of questions from enthusiastic students. Still he lectured in the same slow, deliberate way, making certain that every point he made could be readily absorbed by the young mind. Right to the end, he kept an open mind on all he taught, and recognised and usually knew a great deal about any of the latest zoological developments. However, he was not above having his attention drawn by his students to anything new and then modifying his lecture notes accordingly; lecture notes, incidentally, that may well be jotted down on any scrap of paper, the back of a telegram, or on the insides of opened-up, used envelopes. The abstract of his paper delivered at the last A.N.Z.A.A.S. Congress which he attended, he sent me (as secretary of Section D) on a sheet of paper, which he had folded and stuck together with stamp edging, addressed on the outside, and forwarded with no envelope!

The conception he had of the breadth of his subject is clearly shown in the 1936 Centenary Address he gave on "A Hundred Years of Zoology in South Australia." In this address, which was one of the series of contributions by the Royal Society of South Australia to the celebration of the Centenary of the State of South Australia, he indicated briefly the work then still to be done in the systematic, parasitological, ecological and embryological fields, as well as fisheries problems, cytology and genetics.

Again Johnston had the same experience in Adelaide as he had had in Brisbane, his department acquired new quarters. In 1939, it was shifted to occupy half of the new Benham Laboratories, which were made possible by a £46,000 bequest "to encourage the study of natural history," and built near the Torrens River. This was the department I knew, when I joined him in 1943. It is a long, three-storied building, one end being occupied by Botany and the other by Zoology. Mounting the few stone steps into the department, one enters a world characterised by its feeling of serenity, stability and neatness. Wide halls have mounted photographs of Antarctic animals on their walls, and the museum is truly indicative of the orderliness which permeates the whole department. This museum, besides the usual range of specimens, possesses the complete skeleton of a young elephant (Nellie!), and has as well an interesting and useful series of hand-made models, done in baked clay and painted by one of Johnston's own students under his direction.

The Professor had a big office, always very tidy, and from this one went through to a smaller laboratory, where there were shelves and shelves of bottled specimens, all meticulously labelled and sorted. In a minute he could put his hand on any single thing. Throughout the department, everything had its proper home, and, what is more, was usually there. The one room in the whole building quite out of its setting was mine, and whenever he paid me a visit, which was often, Professor Johnston always had a very busy time squaring things up on the bench or the table, a small characteristic of his which frequently came to the fore.

In Adelaide, just as one would expect, his outside interests grew. He was President of the Zoology Section of the Australian and New Zealand Association for the Advancement of Science in 1923 at the meeting held in Wellington, New Zealand, and delivered an address on "The Australian Prickly Pear Problem." He was Vice-President of the Section for many of the subsequent meetings and one of the original Fellows, being nominated in 1938-39. It is perhaps fitting that the last A.N.Z.A.A.S. meeting he was to attend was that held in Brisbane in May, 1951, only three months before his death. This was the first time he had returned to Brisbane since he had left about 30 years earlier. At this Congress he was particularly active, and his fund of knowledge never seemed to be exhausted; there was always something from him, on Marine Biology, Antarctic studies, Parasitology, and so on. It was almost as though he realized that the sands of time were running out, and he wanted to give of all he knew.

He had joined the Royal Society of South Australia in 1921, so beginning a long association with it. Besides publishing many papers from his Adelaide department in the Transactions, he served on the Council in several capacities. He was President in 1931-32; several years later, from 1937-40, he was secretary, and in 1943-45, editor. As an editor he had vast experience, and it is but one of the many activities that he performed with meticulous care; he had the patience and tenacity of purpose desirable in a good editor.

From very early in his career Professor Johnston took a keen and active interest in Museum work. He was appointed as Honorary Zoologist to the Australian Museum in 1909, to the Queensland Museum in 1911, and to the South Australian Museum in 1924. As an honorary associate, he served the South Australian Museum over a long period, and was elected by the Royal Society of South Australia as a member of the Board of Governors of the Public Library, Museum and Art Gallery of South Australia. He sat on the Board from May, 1927, until September, 1929, and in 1928, on the death of Mr. E. Waite, he became Honorary Director of the Museum for about three years. Later, in 1931, he was again elected on the same Board of Governors by the University of Adelaide, continuing in this capacity until 1940, when the composite board was disbanded and each institution acquired its own Board. During this period on the composite board, he had been Chairman of the Museum Committee from 1935 and had strongly advocated that each institution should have its own Board. On the formation of an independent Board for the Museum, the South Australian Government appointed him as Chairman, which office he retained until his death.

He also served over a long period as secretary of the Handbooks Committee of South Australia, and in this capacity he had the unenviable task each year of budgeting for the costs of the Handbooks produced. These publications are of great importance to Australian biological sciences. Since 1919, Johnston was a member of the Australian National Research Council.

He was also deeply conscious of the contributions that could be made to the public health and welfare, both through his department and his own knowledge. Not only did he become a member of the Advisory Committee on Water Supplies in South Australia, but for many years a record was kept by a member of his staff of the algae and other organisms (excluding bacteria) present in the local reservoirs. His advice on the biological aspects of sewage disposal at the Glenelg Treatment Works was also sought.

Within the University, he performed many tasks outside that of being the head of the Department of Zoology; he acted as Professor of Botany from 1928-34; served as Dean of the Faculty of Science several times, and on the last occasion, when it was his turn to assume the task once more, he was big enough to refuse it because he felt that he could not do it justice. Again we see a man with high ideals and endeavouring to live by them.

In South Australia, just as in Queensland, the career of Professor Harvey Johnston shows how keenly sensitive he was to the value of field work in his subject. This was an enthusiasm that persisted throughout his lifetime. In 1929 he, in Sir Douglas Mawson's own words, "was easily persuaded to join the staff of the British Australian and New Zealand Antarctic Research Expedition as Chief Zoologist". He went on the two cruises of the Discovery I. between 1929-31, and was described by Mawson as being "indefatigable in his collecting work". The biological programme was mainly of marine investigations in the South Atlantic Ocean, but landings had been made at various places, including both Heard and Macquarie Islands. Specimens were collected, recorded, preserved, labelled and stored away for further work later, and he still found time to collect parasites. This endless work was, presumably, made the more creditable because of the proneness to sea-sickness which apparently persisted throughout his lifetime. These Antarctic adventures were to provide him for the rest of his life with a wealth of anecdotes, and it was always to the delight of his students that he could easily be persuaded to talk of his travels.

On returning to Australia, he was given the task of editing the Expedition's Zoological and Botanical Reports—several of which he himself prepared. He had already contributed a great deal in the editing of the final numbers of the same series of the earlier Antarctic Expedition of 1911-14, after the death of Professor Haswell. The death of Professor Johnston has set back the publication of several more of these reports. Only a week before he died, a Report by himself and Muirhead on *Cephalodiscus,* had just been issued. At the time of his death, he was supervising work on the B.A.N.Z.A.R.E. collections of Nematodes, Cestodes and Trematodes, to which had been added specimens collected recently at Heard and Macquarie Islands by the Australian National Antarctic Research Expedition. For his Antarctic Expedition, Harvey Johnston was awarded the Polar Medal in 1934.

In Adelaide, Johnston had linked up again with his earlier colleague Professor J. B. Cleland, with whom he became associated in still more scientific work. He accompanied Cleland and his party on many of the yearly Anthropological expeditions to various parts of Central Australia between 1929-37. The scientists travelled by train to Alice Springs, and from there continued to their particular destination by car and truck. Again I can do no better than to quote what Professor Cleland has written to me:

"Harvey Johnston was my tent companion and working colleague in a number of the Anthropological expeditions through the interior—a very helpful and considerate companion. We did the blood grouping together. Whilst I did the blood tests, he searched the heads of the natives for head lice, made blood smears, took finger prints and hand prints and solaced over willing victims with sweets or a plug of tobacco—both very acceptable. He was always particularly neat and tidy and our working tent was, in consequence, a model in this respect as well as his sleeping bag and gear."

As well as these tasks, Johnston never missed an opportunity to collect his beloved helminths. Natives would bring in animals and carefully he would examine them, particularly the gut content for worms. As a result, through the papers he subsequently published, our knowledge of the helminths of the fauna of Central Australia has been much enriched.

Characteristically, on these expeditions Johnston did not limit his investigations to his own particular scientific fields, but also took a keen interest in the Australian aborigines about whom he became very knowledgeable. This was an interest that his wife shared with him. In 1927-8 he was President of the South Australian Anthropological Society.

And still outside honours came to him. Among these, in 1934 he was awarded by the Royal Society of South Australia the Sir Joseph Verco Medal for distinguished scientific work, and in 1939 from A.N.Z.A.A.S. came the much coveted Mueller Medal. This award was made for his investigations in the biological control of prickly pear in Australia, and in Australian and Antarctic parasitology. He had long been a Corresponding Member of the Zoological Society of London, a Corresponding Member of the Helminthological Society of Washington, and a Foreign Member of the American Association of Economic Entomologists. His interest in entomology had never waned, and in 1935-37 he was President of the South Australian Entomological Society.

It is typical of this man that, despite all these activities, he visualised and embarked upon a long term project which was still in operation at the time of his death. This was an extensive investigation into the parasites of both birds and mammals of the lower Murray. Here he found the material for unravelling complicated life cycles of a great number of flukes. It was a slow, tedious job; the mollusc fauna had to be carefully studied for cercarial infection. Every excursion meant that material would be collected, taken back to the laboratory, sorted, and every snail or bivalve segregated into its own small tube, so that their infection, if present, could be detected. Sometimes, too, larger animals, perhaps a snake, a bird or a lizard would be captured, brought back to the laboratory, and searched meticulously for its parasites. Usually the Professor himself would carry out these examinations, and invariably he would find something of great interest, often after a long, slow, painstaking hunt. Then with great joy he would call his students into his private laboratory and proudly show them the treasures he had found.

Tailem Bend was the place he frequented and loved most. Nearly all of us who were with him in Adelaide have at one time or another accompanied him on one of these day trips to the Jaensch's property, right on the river. Many are the stories that may be told of odd professorial accomplishments on these trips—as on the occasion when the Professor slithered down the slippery muddy bank of the Murray and disappeared, to leave only a floating hat. Then there were to be seen only bubbles, and soon afterwards the Professor. He had come up immediately under his hat, and emerged, wet, somewhat unusually dishevelled and not particularly neat, but still wearing his hat!

Right up to the time of his death, Professor Johnston was actively engaged in working on the life cycles of various flukes. He had an almost uncanny ability to postulate what would be the necessary intermediate hosts, and with each trematode life history discovered, he would with the help of his staff almost invariably prove his theories to be quite correct. Only a week after his death, there was completed in his department another trematode life cycle that he had predicted. Having traced the developmental stages of a fluke, which lives in the bursa Fabricii of the seagull, through a gastropod, *Bembicium*, and then a small lamellibranch, the adult fluke was found in the final host just as he thought it would be.

During the last few years of his life, Professor Johnston's health had somewhat deteriorated. In 1945 he had a stroke, and for a long time afterwards was unable to turn his head completely to the right. In 1949 it was a very great sorrow to him when his only son died suddenly. However, when in May, 1951, he came to Brisbane, he looked amazingly well, and we had hoped that he would be able to retire and complete much of the work that he still wanted to do. He was really quite well until the last week of his life, and then he was only "not feeling well" for several days. On Thursday, August 30th, while dressing to attend the meeting at which his successor in the Zoology Department was to be selected, he suddenly collapsed and died. He was cremated on the following day.

Professor Harvey Johnston leaves behind him in the hearts of many the picture of a gentle man, clear thinking, sensitive and with a slow, quiet sense of humour. His particular type of humour is perhaps well shown by this incident. From the Jabiru, which is one of our largest birds, he recovered a new very small cestode. This he described soon after Professor Cleland's first daughter was born, calling it *Clelandia parva.*

He was a man proud of his students and their achievements, unassuming in his manner, almost hesitant at times when making requests for himself, but nevertheless, if the occasion demanded it, having the capacity for fiery retort and argument. Being human, he had human faults and failings; but his life may truly be said to have been one in which sincerity, square conduct and kindliness were keynotes. He had, again to quote Cleland: ''an ethical code that he lived up to and to which few of us can attain''. It is small wonder that there were so many so extremely fond of him. Many, like myself, will not have realised fully and appreciated the breadth of the knowledge and the greatness of this very approachable person. In some degree, his greatness is reflected by the fact that he admitted openly that, of his papers, he wished he had not published one half!

Professor T. Harvey Johnston has left Australia greatly enriched in biological knowledge, particularly in the field of parasitology. Perhaps, he may even be regarded one day, as the Father of Australian Helminthology. Our heritage is a great one. While perhaps some of his work will have to be revised as new horizons open up in genetics, physiology, ecology and perhaps even radical new ideas appear, still much will endure. Into the hands of workers today, Professor Johnston has thrust a brightly burning torch; ours will be the task to keep that flame alight.

For me, the late Professor Harvey Johnston will always be a fitting example of a complete man in the sense used by Greek philosophers; for according to their standards: ''The complete man is not the man who has the most knowledge, but he is the one who is the best equipped to acquire it''.

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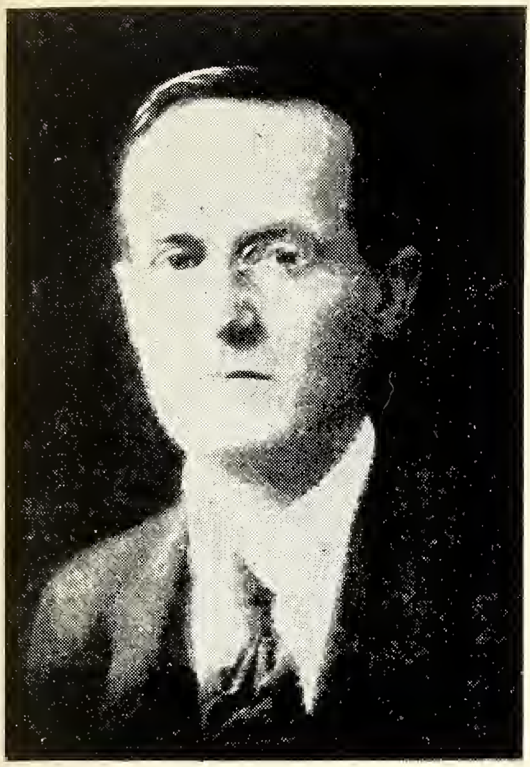
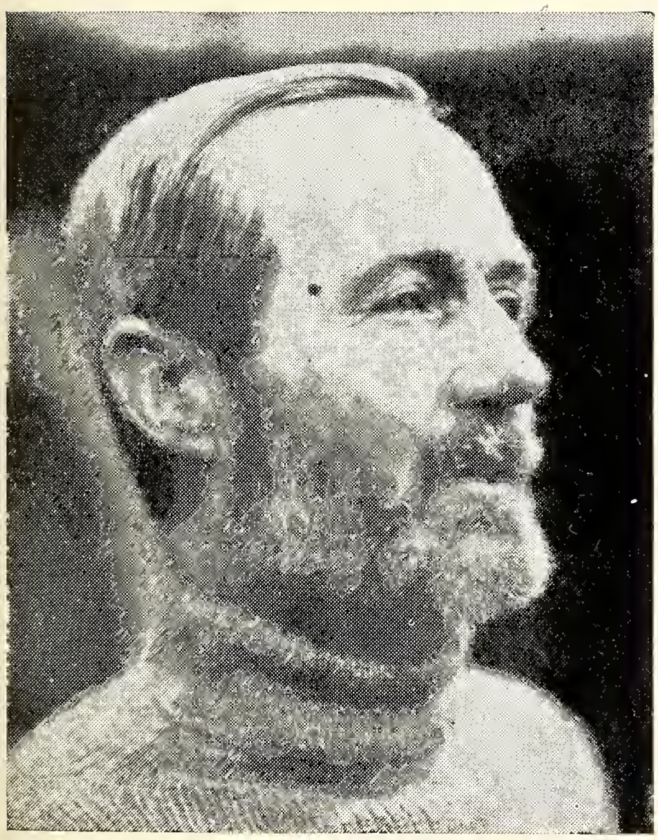
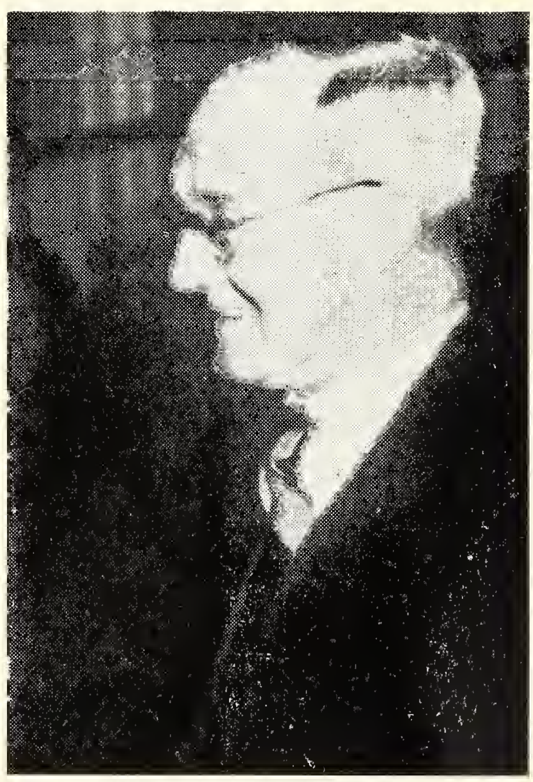
I would like to express my thanks to every one of the many friends from whom I obtained information and stories, which I have been able to piece together into this whole. Outstanding amongst these are: Mrs. Johnston, Dr. F. Bage, Dr. M. J. Mackerras, Professor H. J. L. Wilkinson, Mr. J. B. Watkins, Dr. C. D. Gillies, Professor J. B. Cleland, Professor Sir Douglas Mawson, Mr. H. M. Hale, Mr. Duncan Swan, Professor O. W. Tiegs, and Mr. K. Salter. There are also many others, too numerous to mention individually. I hope that each will take this as a personal expression of my sincere appreciation. Also my thanks are due to the librarians of the several institutions, who so kindly helped in seeking out information and numerous references, particularly Mrs. M. Macgregor of the Queensland Institute of Medical Research and Miss N. Turnbull of the Queensland Museum. For the photographs of Professor Johnston, I must thank Dr. M. J. Mackerras, Professor Sir Douglas Mawson, and Mrs. M. Macgregor.







Thomas Harvey Johnston.

Top left: In Sydney, 1911. Top right: On bank of Burnett River, near Eidsvold, Queensland, 1917. Bottom left: On the Antarctic Expedition, 1929-31. Bottom right: At the A.N.Z.A.A.S. Meeting, Perth, August 1947.

The Royal Society of Queensland.

Report of the Council for 1951.

To the Members of the Royal Society of Queensland.

Your Council has pleasure in submitting the Annual Report of the Society for the year 1951.

At the Ordinary Meetings throughout the year, four addresses were given. Symposia were held at two meetings, and one evening was devoted to exhibits.

Several original papers were accepted for publication in the Proceedings. During the year, Volume LXI. (1949) of the Proceedings was issued and Volume LXII., which includes the C. T. White Memorial Supplement, is nearing completion.

The Society's Library is to be moved early in 1952 to a new location in the University, George street. Additions to the Library total approximately 1,500 volumes and parts, some of which are back-numbers recently provided. Twelve new exchanges have been established. A total of 67 volumes from the library are at present being bound and the thanks of the Society are due to the Government for a grant to meet half the cost. The cataloguing of the library is proceeding gradually.

During the year the Society has approved of financial support to the Marine Biological Station Fund of the Great Barrier Reef Committee, and to the Australian National Research Committee of Radio Science for the International Scientific Radio Union Assembly to be held in Australia in 1952.

Professor Hines and Miss Scott were appointed delegates for the Society to the Council of A.N.Z.A.A.S., which held a meeting in Brisbane during May, 1951.

There are now 6 honorary life members, 8 life members, 3 corresponding members, 229 ordinary members and 9 associate members in the Society. During the year the Society lost one member by death, and 13 by resignation; 10 ordinary members and 1 associate member were elected. Mr. F. Gipps, one of the Society's earliest members, was elected to honorary life membership.

Attendance at Council Meetings was as follows:—H. J. G. Hines, 9; M. F. Hickey, 4; I. M. Mackerras, 8; M. I. R. Scott, 8, D. F. Sandars, 9; F. S. Colliver, 8; S. T. Blake, 8; G. Mack, 8; M. J. Mackerras, 6; A. L. Reimann, 5; J. H. Simmonds, 8; W. Stephenson, 7; L. J. H. Teakle, 7.

H. J. G. HINES, President.

MARGARET I. R. SCOTT, Hon. Secretary.

DOROTHEA F. SANDARS, Acting Hon. Secretary.

THE ROYAL SOCIETY OF QUEENSLAND.

STATEMENT OF RECEIPTS AND EXPENDITURE FOR YEAR ENDED 31st DECEMBER, 1951.

Receipts.

	£	s.	d.	£	s.	d.
Balance in Commonwealth Bank 31/12/50	557	3	2			
Cash in Hand, 31/12/50	4	5	0½			
				561	8	2½
Subscriptions:—						
1951 Membership	232	10	0			
Arrears	59	0	6			
In Advance	8	0	0			
				299	10	6
Commonwealth Loan Interest	9	6	1			
Commonwealth Savings Bank Interest	9	2	3			
				18	8	4
Donation				0	5	0
Sale of Reprints and Society Proceedings				58	8	0
Exchange				0	18	2
Refund on Commonwealth Loan Investment				1	4	0
				£940	2	2½

Expenditure.

	£	s.	d.	£	s.	d.
Watson Ferguson & Co.—						
Cost of Vol LXI. (1949)	281	8	6			
Less Government Subsidy	139	19	6			
				141	9	0
Library Insurance				2	8	0
Roneoing				5	2	6
Lanternist				3	0	0
Stationery, Stamps, &c.—						
Secretary	28	6	11½			
Treasurer	1	1	6½			
Librarian	8	16	9			
				38	5	3
Refreshments and Utensils	7	1	4½			
Less Collections	4	10	0			
				2	11	4½
Printing, &c.—						
Account Forms and Receipt Book	13	7	0			
Headed Paper and Envelopes	12	4	7			
Rubber Stamp and Block	1	2	6			
				26	14	1
Donations—						
Barrier Reef Marine Biological Stn.				20	0	0
Investments—						
Commonwealth Loan Bond				120	0	0
Balance in Commonwealth Bank, 31/12/51				563	6	8
Cash in Hand—						
Secretary	0	15	3½			
Treasurer	6	13	9½			
Librarian	9	16	3			
				17	5	4
				£940	2	2½

The amount of £27 11s. 0d. is still owing on Volume 41; being for plates re-done.

In addition to the Credit Balance shown in the above Statement, the Society holds the following Capital Funds:—

Commonwealth Loan	£200
Savings Certificates	2
	£202

Examined and found correct.
L. P. HERDSMAN, Hon. Auditor.

Held in safe custody by the Commonwealth Bank of Australia, Adelaide street, Brisbane.
DOROTHEA F. SANDARS, Hon. Treasurer.

Abstract of Proceedings, 31st March, 1952.

The Annual General Meeting of the Society was held in the Physiology Department of the University of Queensland, on Monday, 31st March, with the President, Associate Professor H. J. G. Hines, in the chair. About forty-eight members and friends were present.

The President expressed appreciation of the long service given by Miss M. I. R. Scott as Secretary of the Society, who is leaving the State and consequently has resigned. It was moved and seconded that a special letter of thanks be written to Miss Scott.

The following members were elected as Office Bearers for 1952:—

President: I. M. Mackerras.
Vice-President: S. T. Blake.
Hon. Secretary: Miss D. F. Sandars.
Hon. Treasurer: Miss E. N. Marks.
Librarian: F. S. Colliver.
Editor: George Mack.
Councillors: Miss K. Robinson, W. Stephenson, M. Shaw, L. J. H. Teakle, J. H. Simmonds.
Hon. Auditor: L. P. Herdsman.

The Presidential Address, "Some Biochemical Aspects of Reactions to Heat and Cold," was delivered by Associate Professor H. J. G. Hines.

Abstract of Proceedings, 28th April, 1952.

The Ordinary Monthly Meeting of the Society was held in the Physiology Department of the University of Queensland, on Monday, 28th April. Owing to the absence of Dr. I. M. Mackerras, Associate Professor Hines acted as chairman for the evening. About twenty-one members and friends were present. The minutes of the previous meeting were confirmed. The following were nominated for membership:—Miss P. Lee, Captain F. Rose and Mr. B. R. Ayling for Ordinary Membership, and Miss L. Emanuel and Miss M. McCaffrey for Associate Membership.

Professor H. C. Webster gave an address entitled "Recent Impressions of Physics in Great Britain." Most interesting developments have occurred in the study of fundamental sub-atomic particles and several new particles—various kinds of 'meson'—have been discovered in recent years, particularly at Bristol. The work at this centre has the merit of simplicity; photographic plates are sent to great heights in plastic balloons then, after recovery, developed and examined. For further investigations of these particles several highly costly machines are under construction, including a cyclotron at Liverpool, a synchrotron at Glasgow and a cyclo-synchrotron at Birmingham. At other centres, studies of the atomic nucleus are being made with a view to revealing the nature of the nuclear forces. In biophysics, investigations include the study of the 'crystal structure' of biological entities such as protein molecules and the examination of the action of X-rays on living organisms. British developments in Astrophysics include those in the new science of radio-astronomy—the location of stars by the radio waves they emit.

Abstract of Proceedings, 26th May, 1952.

The Ordinary Monthly meeting of the Society was held in the Physiology Department of the University of Queensland, on Monday, 26th May, with the President, Dr. I. M. Mackerras in the chair. About twenty-seven members and friends were present. The minutes of the previous meeting were confirmed. The following were elected to membership:—Miss P. Lee, Captain F. Rhodes, Mr. B. R. Ayling to Ordinary Membership; and Miss L. M. Emanuel and Miss M. McCaffrey to Associate Membership. Mr. R. Endean, Dr. I. Hiscock and Professor J. Francis were nominated for membership. The Librarian reported the addition of 173 volumes.

Mr. George Mack exhibited several snakes. He referred to the great public interest in these reptiles, and expressed regret at the tendency to condemn all species when only a few could be described as potentially dangerous.

Mr. R. Endean exhibited littoral echinoderms from collections made between the Tropic of Capricorn and the Queensland-New South Wales border. The series indicated something of the range of morphological variation to be found in these waters. Of interest was the finding of successive juvenile stages of the 'pincushion' star-fish, *Culcita novaeguineae* and the frequent occurrence of disc and brachial schizogony in *Nepanthia belcheri* and *Linckia guildingii* respectively. The majority of holothuroids found belong to the Aspidochirotae. The close resemblance of the fauna to that of Lord Howe Island was discussed.

Dr. M. J. Mackerras and Miss D. Sandars exhibited lung-worms from marsupials. *Plectostrongylus fragilis* from the marsupial mouse, *Antechinus flavipes,* and *Marsupostrongylus bronchialis* from the bandicoot, *Isoodon obesulus,* were described. The relationship of the hosts and the parasites was discussed and the diet of the hosts considered. Reference was made to the South American opossum, the only other marsupial in which lung-worms are known to occur. It was postulated that the occurrence of the parasites may possibly be correlated with the habits of their hosts, rather than with the phylogeny of their hosts.

Mr. J. O'Hagan described the methods used for the characterisation of proteins and the estimation of individual proteins in a mixture by electrophoresis on filter paper. Staining of the paper revealed the proteins as coloured spots. Instances were given of the application of the method in the diagnosis of disease states by the electrophoresis of serum from the patient.

Mr. R. L. O'Neill noted that oddities in crystal formation in minerals may be worthy of study in connection with the occurrence of ores, in that they are indicative of temperature and volumetric conditions of crystallisation.

Professor M. Shaw exhibited two instruments, one of which was an Angle Bekkor for fine measurements of angles by rising collinated light. After explaining the principle of the instrument, Professor Shaw presented some ideas of how it could be used to measure angles and surface flatness. The other was a Light Wave Micrometer, which illustrated the use of light waves for percussion measurement. The instrument was used to measure the deflection of a 3½-inch diameter steel bar under finger pressure.

Abstract of Proceedings, 30th June, 1952.

The Ordinary Monthly Meeting of the Society was held in the Physiology Department of the University of Queensland on Monday, 30th June, with the President, Dr. I. M. Mackerras, in the chair. About forty-three members and friends were present. The minutes of the previous meeting were confirmed. The following were elected to Ordinary Membership:—Mr. R. Endean, Dr. I. Hiscock and Professor J. Francis. Dr. T. E. Woodward, Dr. Sprent and Mr. C. A. Appleby were nominated for Ordinary Membership. The Librarian reported that there had been 273 additions to the Library.

Dr. O. A. Jones exhibited seismograph records of the recent Maryborough earth-tremor from the University Seismological Station.

Mr. R. H. Greenwood gave an address entitled "Our Lopsided Earth." It was pointed out that the disparity between the amount of fertile, well-watered country in the middle-latitude regions of the Northern and Southern Hemispheres, the separation of the closely-settled European and Oriental realms by an extensive zone of mountainous and desert land, and the marked concentration of coal and iron ore deposits in Northern Hemisphere middle-latitude regions have resulted in a very unequal distribution of man and his productive activities throughout the world. About 85 per cent. of the world's people live in the Northern Hemisphere. The demand for European manufactured goods has been restricted by industrialization of other lands and it seems essential in the long run for the European economic problem to be alleviated by increased emigration to the New World. Further development of the tropics, involving technological improvements in productivity, will be necessary in order to produce food and raw materials that the New World will be less able to export with a growing population. While emigration alone could not be on a scale large enough to relieve the population problems of Japan, China, India and Pakistan, further industrialization might help, provided that the tropical parts of south-east Asia and Africa could be developed to supply more raw materials and to absorb more Asiatic manufactured goods.

Abstract of Proceedings, 28th July, 1952.

The Ordinary Monthly Meeting of the Society was held in the Physiology Department of the University of Queensland, on Monday, 28th July, with the President, Dr. I. M. Mackerras, in the chair. About twenty-eight members and friends were present. The minutes of the previous meeting were confirmed. The following were elected to Ordinary Membership:—Dr. T. E. Woodward, Dr. J. Sprent and Mr. C. A. Appleby. The Librarian reported that there had been 150 additions to the Library.

Professor W. Bryan exhibited rocks from Mount Lamington, New Guinea, which had been collected after the eruptions during January, 1951. In fiery cloud eruptions of this sort, more common than was once realised, there are ejected great clouds of incandescent particles.

Professor F. T. M. White delivered an address entitled "Some Varied Aspects of a Recent Overseas Visit." In dealing with the mines at Witwatersrand, South Africa, he mentioned that the presence of Thucholite, a pegmatitic mineral, believed to be pseudomorphous after Uraninite in the auriferous conglomerate (Banket), may revive controversies over the theoretical explanation of the origin of the gold. He then contrasted the incidence of Silicosis in South Africa with the fact that 'classical silicosis' is unknown on the Kolar Gold Field, Mysore, India, where a highly silicious ore is also mined under conditions of 'dry' mining and extreme temperatures, and suggested possible explanations for the differences. Mention was made of a disease known as Sporotrichosis which is related to fungus growth particularly on *Eucalyptus salignia* and *Acacia mollissima,* two Australian timbers used extensively underground on the Rand. Physiological effects of the temperature and humidity conditions in the working environment of the Kolar mines at depths between 9,000-10,000 feet were outlined and the necessity for acclimatisation of workers was stressed.

The archaeological background to copper mining on Cyprus from the days of the Phoenicians to the present time was discussed, and the speaker concluded his remarks with a note dealing with the history of the island from its former possession in 1191 until its re-integration as part of the British Empire in 1925.

Abstract of Proceedings, 1st September, 1952.

The Ordinary Monthly Meeting of the Society was held in the Physiology Department of the University of Queensland, on Monday, 1st September, with the President, Dr. I. M. Mackerras in the chair. The minutes of the special meeting held on 28th July, and of the ordinary meeting held on that date were confirmed. The following were nominated for membership:—Dr. R. Tucker for Ordinary Membership; and Mr. R. Dwyer, Miss Y. Battey and Miss C. Henry for Associate Membership. The Librarian reported that there have been 86 additions to the Library.

Dr. O. A. Jones exhibited some geological specimens from the Mount Isa district and a portable Geiger Counter.

Professor J. Francis gave an address entitled "Preventive Medicine." Major epizootics which had for long swept back and forth over Europe, as they were carried by the movements of armies and by trade, were particularly severe during the 18th and 19th centuries. Cattle Plague or Rinderpest is believed to have destroyed 200,000,000 cattle in Europe during the 18th century and it was largely due to the ravages of this disease that the Veterinary Colleges were established. England was relatively free until about 1840 when live animals were imported from Europe for food for the increasing population. Foot and mouth disase, pleuropneumonia and, later, cattle plague inevitably followed. Although, since 1863 all the major epizootics had been classified as infectious, and quarantine periods had been laid down, it was not until the Cattle Disease Prevention Act, which provided for the slaughter of infected animals and those in contact with them, was introduced in 1866, that cattle plague was brought under control. Subsequent legislation has led to the eradication of pleuropneumonia, glanders and rabies from Great Britain and tuberculosis is now being controlled energetically.

Where the incidence of a disease was high, it has not been possible to take such drastic measures and immunization has been used. The use of various vaccines was outlined. During recent years drugs had been developed to control various bacterial infections. Reference was made to the control of mastitis and the development of 4, 4-diamino-diphenyl sulphone for the treatment of human leprosy. Attention was drawn to the effect of preventive medicine and the growth of human populations. It was contended that Malthus' dictum that populations tended to increase by a geometric ratio but food production by an arithmetic ratio was still true; in the long run a reasonably low world birth rate was the only alternative to the traditional checks of disease, starvation and war.

Abstract of Proceedings, 29th September, 1952.

The Ordinary Monthly Meeting of the Society was held in the Physiology Department of the University of Queensland, on Monday, 29th September, with the President, Dr. I. M. Mackerras, in the chair. The minutes of the previous meeting were confirmed. The following were elected to membership:—Dr. R. S. Tucker to Ordinary Membership, and Miss C. Henry, Miss Y. Battey and Mr. R. Dwyer to Associate Membership. The Librarian reported that there have been 134 additions to the Library.

Abstracts of the following papers were delivered:—

"The Identity of *Spadella moretonensis* Johnston and Taylor," by J. Thomson.

"Faulty Rain-recording," by Captain F. Rhodes.

"Volcanic Rocks of Aitape, New Guinea," by G. Baker.

Mr. W. Dall exhibited prawns from Moreton Bay. Hitherto river prawners have caught only small immature individuals of two species, *Metapenaeus monoceros* and *M. macleayi.* Three additional commercial species, *Penaeus esculentus, P. plebejus* and *P. merguiensis,* all large prawns, are being caught in Moreton Bay. Five other species are taken fairly commonly, while two new species have been found to date.

Professor F. N. Lahey exhibited a number of new products isolated from Queensland plants and forming the bases of some of the organic chemical research being carried out at the University, St. Lucia. They included the new yellow alkaloid, acronycine, from *Acronychia baueri,* the tetracyclic triterpene, ebricoic acid from the tree-rotting fungus, *Polyporus anthracophilus,* and two new coumarins, halfordin and isohalfordin, from *Halfordia schleroxyla.*

Mr. H. J. T. Bake demonstrated the inflammability of solid fuel that had proved to be hexamine.

Abstract of Proceedings, 27th October, 1952.

The Ordinary Monthly Meeting of the Society was held in the Physiology Department of the University of Queensland, on Monday, 27th October, with the President, Dr. I. M. Mackerras, in the chair. About thirty-one members and friends were present. The minutes of the previous meeting were confirmed. The Librarian reported that there had been 150 additions to the Library.

A discussion on "Observations in Torres Strait" was held, the speakers being Dr. M. J. Mackerras, Dr. E. N. Marks and Dr. D. Hill.

Dr. M. J. Mackerras gave a brief account of an epidemic of malignant tertian malaria, which occurred on Murray and Darnley Islands earlier in the year. On Murray Island, with a population of about 461, there were 11 deaths and 60 proven cases of malaria. On Darnley Island, with a population of 289, 45 per cent. were found to be infected, but the disease was mild and there were no deaths. It is evident that malaria has not been endemic on either island; the spleen rate was low, and the distribution of parasites in the different age groups quite different from that which occurs in a hyperendemic area such as Wewak. It seems likely that the parasite was brought to Murray Island in 1951, and that the infection built up to epidemic proportions following the great increase in mosquito abundance after the wet season.

Dr. E. N. Marks gave an account of the mosquitoes. Nine species were found on Murray Island and twelve on Darnley Island, seven being common to both. One species of Anopheline, *Anopheles farauti*, which is known to be an efficient vector of malaria, was taken. It was suggested that in the period of north-west monsoons, from December to April, many rain-filled puddles and brackish pools at mouths of creeks would provide suitable breeding places for *A. farauti* and the population should be at its maximum in the warm still period following the monsoons. *Aedes aegypti* was found only on Murray Island and *A. scutellaris* only on Darnley Island. They have similar habits and it seems likely that the introduced *A. aegypti* has difficulty in establishing itself in competition with the native *A. scutellaris*. *A. kochi* was a pest species on Murray Island. Nearly all the species taken occur both in Australia and New Guinea. *Harpagomyia leei* is known only from New Guinea and Darnley Island and an undescribed species of *Aedes* (*Macleaya*) only from the latter.

Dr. Dorothy Hill said that Murray and Darnley Islands which lie between Cape York Peninsula and New Guinea are the only volcanic islands on the Great Barrier Reef. The volcanoes are of the central type and the islands are built up of flows of augite and olivine basalts and ash. During explosive phases of the volcanic activity, parts of the coral reef were incorporated as boulders in the ash beds and these boulders have been dolomotised and silicified. The only two recognisable species of coral in these boulders are still living on the same reef.

Abstract of Proceedings, 1st December, 1952.

The Ordinary Monthly Meeting of the Society was held in the Physiology Department of the University of Queensland, on Monday, 1st December, with the President, Dr. I. M. Mackerras, in the chair. About seventy members and friends were present. The minutes of the previous meeting were confirmed. The Librarian reported that there have been 184 additions to the Library.

The President, Dr. I. M. Mackerras, presented, on behalf of the Council of A.N.Z.A.A.S., the 1952 Mueller Medal to Mr. Heber A. Longman. The years of devoted service to, and interest in, natural science that had been spent by Mr. Longman were outlined by Dr. Mackerras and supported by Associated Professor Whitehouse.

Miss D. F. Sandars delivered the Memorial Lecture entitled "Professor T. Harvey Johnston: First Professor of Biology in the University of Queensland."

List of Members.

Honorary Life Members.

Ball, L. C., B.E.	38 Dorchester St., South Brisbane, Q.
Bennett, F., B.Sc.	Kin Kin, *via* Gympie, Q.
Gipps, F. G.	"Corymbosa," Eagle Heights, Mt. Tamborine, Q.
Longman, H. A., F.L.S.	River Tce., Chelmer, Brisbane, Q.
Simmonds, J. H., Senr.	Hillsdon Rd., Taringa, Brisbane, Q.
Walkom, A. B., D.Sc.	Australian Museum, College St., Sydney, N.S.W.

Life Members.

East, J. D., B.Sc.	District Geologist's Office, Rockhampton, Q.
Francis, Professor J., M.Sc., M.R.C.V.S.	Veterinary School, University of Queensland, Brisbane, Q.
Herdsman, L. P.	Government Printing Office, George St., Brisbane, Q.
Higginson, H. L., B.Sc.	Patent Office, Canberra, A.C.T.
Jensen, H. I., D.Sc.	Post Office, Caboolture, Q.
Perkins, F. A., B.Sc.Agr.	Entomology Dept., University of Queensland, Brisbane, Q.
Riddell, R. M.	Dept. of Public Instruction, Brisbane Q.
Sanders, Dorothea F., M.Sc.	Q.I.M.R., Herston Rd., Brisbane, Q.
Tilling, H. W., M.R.S.C., L.R.C.T. ..	Nairobi, Kenya, Africa

Corresponding Member.

Gregory, Professor W. K.	Columbia University, New York, U.S.A.

Ordinary Members.

Anderson, B. E.	c/o Cardno & Davies, N.Z. Chambers, Queen St., Brisbane, Q.
Archibald, Lorna, M.Sc., M.B., B.S.	Doughty Av., Holland Park, Brisbane Q.
Atherton, D. O., M.Agr.Sc.	Dept. of Agriculture and Stock, Brisbane, Q.
Bage, Anna F., M.Sc., LL.D.	8 Grove Crescent, Toowong, Brisbane, Q.
Bake, H. J. T.	Gowrie House, Wickham Tce., Brisbane, Q.
Ball, C. W., M.Sc.	Jersey Lead Zinc Mine, Salmo, B.C., Canada
Barker, F.	347 Boundary St., West End, Brisbane, Q.
Barker, G. H.	Adelaide St., Brisbane, Q.
Basire, A. H.	c/o Anglo-Egyptian Oilfields, P.O. Box 228, Cairo, Egypt
Beasley, A. W., M.Sc., Ph.D.	National Museum, Melbourne, Vic.
Beckman, T. J., B.Sc.	Dept. of Agriculture and Stock, Brisbane, Q.
Belford, D. J., B.Sc.	c/o Australian Petroleum Co., Port Moresby, N.G.
Berglin, C. L. W., B.E.	Engineering Dept., University of Queensland, Brisbane, Q.
Berrill, F. W., B.Sc.	Dept. of Agriculture and Stock, Nambour, Q.
Blake, S. T., M.Sc.	Botanic Gardens, Brisbane, Q.

Bleakly, M. C., M.Sc., D.Phil.	Zoology Dept., University of Queensland, Brisbane, Q.
Bostock, J., M.D., B.S., D.P.M., M.R.C.S. L.R.C.P.	Wickham Tce., Brisbane, Q.
Boys, R. S., L.D.S.	P.O. Box 135, Toowoomba, Q.
Braes, E. M.	care of Zinc Corporation, Cobar, N.S.W.
Brameld, H. G., B.E.	Highland Tce., St. Lucia, Brisbane, Q.
Briggs, Mrs. C.	21 Roseby Avenue, Eagle Junction, Brisbane, Q.
Brimblecombe, A. R., M.Sc.	Dept. of Agriculture and Stock, Brisbane, Q.
Briton, N. W., B.Vet.Sc.	Agricultural College, Lawes, Q.
Brockington, T. C.	Bayview Rd., Sandgate, Brisbane, Q.
Browne, H. V.	Otway St., Holland Park, Brisbane, Q.
Bryan, Professor W. H., M.C., D.Sc. ..	Geology Dept., University of Queensland, Brisbane, Q.
Bryan, W. W., M.Agr.Sc.	C.S.I.R.O., George St., Brisbane, Q.
Burns, W. G., B.Sc.	Emperor Gold Mines, Vatukaula, Fiji
Buzacott, J. H., M.Sc.	Sugar Experiment Station, Box 146, Gordonvale, Q.
Caldwell, N. E. H., M.Agr.Sc.	30 Norfolk Rd., Coorparoo, Brisbane, Q.
Callaghan, J. P., M.Sc.	Moggill Rd., Kenmore, Brisbane, Q.
Campbell, K. S. W., B.Sc.	University College, Armidale, N.S.W.
Carter, S., B.Sc.	Mt. Isa Mines Ltd., Mt. Isa, Q.
Casey, J. A., B.Sc.	Bureau of Mineral Resources, Canberra, A.C.T.
Cavaye, Mrs. G., B.Sc.	32 Bennison St., Ascot, Brisbane, Q.
Chamberlain, W. J., D.Sc.	503 Queen St., Brisbane, Q.
Chippendale, F., M.Agr.Sc.	Dept. of Agriculture and Stock, Brisbane, Q.
Clark, C., M.A.	University of Oxford, Oxford, England
Clarke, Harriet	32 Kennedy Tce., Red Hill, Brisbane, Q.
Coleman, F. B.	25 Abbot St., New Farm, Brisbane, Q.
Colliver, F. S.	Geology Dept., University of Queensland, Brisbane, Q.
Common, I. F. B., M.A., M.Sc.Agr. ..	C.S.I.R.O., Box 109, Canberra, A.C.T.
Connah, T. H., M.Sc.	District Geologist's Office, Charters Towers, Q.
Cottrell-Dormer, W., M.Agr.Sc.	Regional Agriculture Office, Inauaia, *via* Kairuku, Papua, N.G.
Crawfoot, A.	Geology Dept., University of Queensland, Brisbane, Q.
Cribb, A. B., M.Sc.	Botany Dept., University of Queensland, Brisbane, Q.
Cribb, H. G., B.Sc.	Geological Survey Office, Brisbane, Q.
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GUIDE FOR THE PREPARATION OF SYNOPSES

1. PURPOSE.

It is desirable that each paper be accompanied by a synopsis preferably appearing at the beginning. This synopsis is not part of the paper; it is intended to convey briefly the content of the paper, to draw attention to all new information and to the main conclusions. It should be factual.

2. STYLE OF WRITING.

The synopsis should be written concisely and in normal rather than abbreviated English. It is preferable to use the third person. Where possible use standard rather than proprietary terms, and avoid unnecessary contracting.

It should be presumed that the reader has some knowledge of the subject but has not read the paper. The synopsis should therefore be intelligible in itself without reference to the paper, for example it should not cite sections or illustrations by their numerical references in the text.

3. CONTENT.

The title of the paper is usually read as part of the synopsis. The opening sentence should be framed accordingly and repetition of the title avoided. If the title is insufficiently comprehensive the opening should indicate the subjects covered. Usually the beginning of a synopsis should state the objective of the investigation.

It is sometimes valuable to indicate the treatment of the subject by such words as: brief, exhaustive, theoretical, etc.

The synopsis should indicate newly observed facts, conclusions of an experiment or argument and, if possible, the essential parts of any new theory, treatment, apparatus, technique, etc.

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If it is necessary to refer to earlier work in the summary, the reference should always be given in the same manner as in the text. Otherwise references should be left out.

When a synopsis is completed, the author is urged to revise it carefully, removing redundant words, clarifying obscurities and rectifying errors in copying from the paper. Particular attention should be paid by him to scientific and proper names, numerical data and chemical and mathematical formulae.

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PROCEEDINGS

OF THE

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OF

QUEENSLAND

FOR 1953

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HIS EXCELLENCY LIEUT.-GENERAL SIR JOHN D. LAVARACK, C.B., C.M.G., D.S.O., C. de G., K.B.E.

OFFICERS, 1953.

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3. The use of italics in the text should be restricted to the names of genera and groups of lower rank, foreign words and titles of periodicals.

4. Except in taxonomic papers, all references should be listed at the end of each paper and arranged alphabetically under authors' names, *e.g.*

   Bagnold, R. A., 1937. The Transport of Sand by Wind. *Geogr. J.*, 89, 409–438.

   Kelley, T. L., 1923. Statistical Method. New York, Macmillan Company. XI+390 pp., 24 fig.

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Vol. LXV., No 1.

Proceedings of the Royal Society of Queensland.

PRESIDENTIAL ADDRESS.

ANIMAL RESERVOIRS OF INFECTION IN AUSTRALIA.

By I. M. Mackerras, Queensland Institute of Medical Research, Brisbane.

(*Delivered before the Royal Society of Queensland, 30th March,* 1953.)

Exactly eleven years ago, in his Presidential Address to this Society, Dr. H. R. Seddon reviewed those diseases of domestic stock, which are derived from direct or indirect association with other animals. My own interest in the parallel problems of human medicine was first stimulated by experience with a classic example, tick-borne relapsing fever, in the Middle East during the last war. In this infection, the spirochaete is happily exchanged between Argasid ticks and small desert rodents, without apparent inconvenience to either. Nothing happened, until enemy activity made the small caves, which were the favourite shelters of the ticks, also attractive shelters for the troops. The ticks obtained a vicarious feed of human blood, and a significant incidence of relapsing fever appeared in the force. Later, we had an exactly similar experience with scrub typhus in jungle training in North Queensland and in jungle warfare against the Japanese.

Seddon was able to find few examples of animal reservoir infections of domestic stock in Australia, although some have been added since. In human medicine, there are many. In world surveys, Meyer (1948) has listed 75 diseases of man which have animal reservoirs, and Wright (1947) has recorded no less than 116 species of parasitic worms which include man at least occasionally among their hosts. Quite a number of these infections occurs in Australia. Some of them have been reviewed individually by various workers, who are listed in Part I. below; the literature about those which have an Arthropod vector has been collected up to 1947 (Mackerras, 1948); and, in an earlier address (Mackerras, 1953), I have touched on some of the general problems involved. Nevertheless, so far as I can discover, no one has attempted to bring the available information about these infections together in one place, in order to take stock of the situation as a whole.

Part I. of this address, then, is an annotated check list of the infections of man in Australia, which are derived from other animals. This has been made as complete as the available information permits, and is arranged systematically according to the infective agents concerned; Arthropod ectoparasites have been omitted, except as vectors of infection. In order to keep an inevitably large bibliography within manageable limits, the first paper listed under each item is, so far as practicable, the most recent in which the previous literature is reviewed, and, unless otherwise clearly stated, the references are only to occurrence in Australia. In Part II., some general problems are discussed from the biological rather than the medical point of view, in an attempt to define weak links in the chain of infection, and to indicate lines on which further research might be pursued.

I am greatly indebted to my colleagues in the Institute and to Messrs. A. K. Sutherland, G. C. Simmons and G. S. Cottew, of the State Animal Health Station, Yeerongpilly, for help in the preparation of the check list, and discussion of the general questions involved, and to Mr. George Mack, Director of the Queensland Museum, for assistance in problems of nomenclature.

PART I.—ANNOTATED CHECK LIST.

Helminthic Infections.

Nematoda.

1. *Trichostrongylus colubriformis* (Giles).—Norman hosts sheep and goats. Intestinal infections in man have been recorded by Heydon and Green (1931), Ross (1937), Heydon and Bearup (1939). Evidence of identification is satisfactory.

2. ? *Trichostrongylus extenuatus* (Raill.).—Normal hosts sheep and goats. Intestinal infections in man have been reported by Heydon and Green (1931). The record is probably valid, but the authors could not completely exclude the possibility of accidental infection of the kids which were fed with larvae cultured from the human faeces.

3. ? *Haemonchus contortus* (Rud.).—Normal hosts sheep and goats. Intestinal infections in man have been recorded by Sweet (1924) and Heydon and Green (1931). Both authors regard their records as doubtful, on account of the risk of contamination by goat faeces in the first, and of accidental infection in the experimental kids in the second.

4, 5. *Ancylostoma braziliense* de Faria and *A. caninum* (Erc.).—Both species are common hookworms of cats and dogs. Larvae in moist, shaded soil attempt to infect man, but can penetrate no further than the skin, in which they may wander for several weeks or even months. The resulting irrigating condition, which is known as "creeping eruption" or "sand worm", is not uncommon in North Queensland, and was elucidated by Heydon (1929, 1931).

6. ? *Habronema* spp.—Normal hosts horses, transmitted by *Stomoxys calcitrans* (L.) and *Musca* spp. The conditions known as "bung eye" in humans is popularly believed to be associated with attack by a fly. Bull (1922), on the basis of histological similarity of the lesions, suggested that it might be caused by attempts by *Habronema* larvae to penetrate the human conjunctiva.

Cestoda.

7. *Echinococcus granulosus* (Batsch).—Dogs are the normal hosts of the adults and sheep of the cysts in Australia, thought other hosts have been recorded. Johnston and Cleland (1937) have summarised the extensive literature on hydatid infection in man up to that date. Recently, Durie and Riek (1952) have demonstrated the existence of a natural cycle in native animals in Queensland, adults in the dingo, *Canis dingo* Meyer, and fertile cysts in the wallabies, *Wallabia elegans*

(Lambert), *W. dorsalis* (Gray), *W. rufogrisea* (Desm.), *W. bicolor* (Desm.) and *Thylogale wilcoxi* M'Coy, with an associated high incidence of sterile cysts in cattle. Earlier workers, of whom Bancroft (1890) appears to have been the first, had found cysts in the following marsupials also: *Macropus major* Shaw, *M. calabatus* L. & G., *Thylogale eugenii* (Desm.), *T. thetis* (Lesson) and *Osphrantor robustus* Gould. Sandars (1952) could find no evidence that the dingo-wallaby cycle was associated with infections in man.

8. *Dipylidium caninum* (L.)—Normal host dog, transmitted by fleas, *Ctenocephalides* spp. Intestinal infections in man have been reviewed by Bearup and Morgan (1939). M. J. Mackerras (unpublished) has recently found two infections in young children in Brisbane.

9. *Hymenolepis nana* (Sieb.)—Normal host mouse, transmission direct, by contamination. Intestinal infections in man are not uncommon, and have been summarised by Sweet (1924).

10. *Hymenolepis diminuta* (Rud.).—Normal host rats, *Rattus rattus* (L.) and *R. norvegicus* (Erxl.), transmitted by various coprophagous insects. Intestinal infections in man have been reviewed by Bearup and Morgan (1939).

11. *Diphyllobothrium ?erinacei* (Rud.).—The spargana of this species have the interesting property of passing from host to host by ingestion, and remaining in the sparganal stage until they reach a suitable Carnivore, in which they complete their development. Sandars (1953) has therefore concluded that the spargana recorded in Australia probably all belong to the one species, and she gives a list of the Amphibian, Reptilian, Marsupial and Eutherian Mammalian hosts in which they are known to survive. Undoubted spargana, which may be strongly suspected to be *D. erinacei,* have been recorded from man by MacCormick and Hill (1907) and Cleland (1915, 1918),* and two doubtful ones by Spencer (1893). Miss Sandars (unpublished) has shown that chilling for six days will kill spargana in meat, which seems an effective way to protect those who like their pork underdone.

Trematoda.

12. *Fasciola hepatica* (L.).—Normal host sheep, developmental cycle in *Simlimnea subaquatilis* (Tate). Infections of man are very rare, but have been reported by Crawford in 1864 (quoted by Sweet, 1909) and by Jeremy and Jones (1935).

13. *Cercaria parocellata* Johnston.—Normal host probably the black swan, *Chenopis atrata* (Lath.), with development in the water snail, *Limnaea lessoni* (Desh.). Attempts by the fork-tailed cercariae to invade the human skin lead to a condition known as bathers' itch, first described in Australia by Johnston (1941) in the swamps of the Murray River in South Australia, and later by Macfarlane (1952) also from lakes near Wagin in Western Australia, with a doubtful record in Narrabeen Lake, New South Wales. Macfarlane confirmed his earlier work in New Zealand, which had shown that the development of persistently itchy papules was due to previous sensitization by the proteins of the cercariae. Dimethyl phthalate was found to protect.

Protozoal and Fungal Infections.

This group is of doubtful validity in Australia. We have no Haemoflagellates that infect man, and are not likely to acquire any,

* Since this was written, a sparganum has been obtained from the thigh of a woman in Queensland (Sandars, unpublished).

because the vectors are either absent (*Glossina, Triatoma*) or rare (*Phlebotomus*). Thus, apart from some ringworms, of which the animal reservoir is undoubted, we are left with *Toxoplasma* and *Sarcocystis** among the Protozoa, and several systemic mycoses among the Fungi, all of which infect man and some other animals. There is a distinct suspicion (Steele, 1952) that the animals may not be reservoirs, but simply victims, like man, of infections derived from elsewhere in the environment. Moreover, in at least one case, recent work indicates that the organisms infecting man may be different from those that infect the supposed reservoir.

14. *Toxoplasma* sp.—Animals found infected include the silver-eye, *Zosterops lateralis* (Lath.) (record doubtful), sparrow, *Passer domesticus* L., sheep, cat, dog, laboratory rabbit, and *Dasyurus quoll* (Zimm.); infections in man are recorded from Queensland, New South Wales, Victoria, Tasmania (unproven) and Western Australia; references in Seddon (1952) and Mackerras (1953).

15. *Sarcocystis* spp.—Recorded from cattle, sheep, pigs, *Rattus norvegicus* (Erxl.) and *R. rattus* (L.) by Johnston and Cleland (1909); probably related forms from *Bettongia grayi* Gould by Bourne (1932) and *Isoodon obesulus* (S. & N.)† by Mackerras *et al.* (1953), and from *Python spilotes* (Lacep.) by Tiegs (1931). We have found no published record of infection in man in Australia, but have seen typical *Sarcocystis* in a section of human cardiac muscle prepared in the Anatomy Department of the University of Queensland. The material was from a child, aged 6, who was accidentally killed; no further information is available.

16. *Histoplasma capsulatum* Darling.—Three infections in man have been described in Australia, by Johnson and Derrick (1948), Inglis and Powell (1953) and Dowe *et al.* (1953). No infections in animals have been recorded here, but dogs and other mammals have been found infected in America. On present knowledge, soil, especially if enriched by fowl or pigeon manure, appears to be the probable source of infection.

17. *Cryptococcus neoformans* (Sanf.) Vuil.—Cox and Tolhurst (1946) record 33 cases of torulosis in man from Queensland, New South Wales, Victoria and South Australia. No infections have been recorded in animals (other than experimental animals) in Australia, but elsewhere horses, cattle and mammals in zoos have been found infected. Fruit has been suspected as a possible source of infection.

18. *Candida albicans* Rob. (Berk.).—Monilial infections in humans are well known in Australia, fatal infections in Queensland being reported by Duhig and Mead (1951). All have been caused by *C. albicans,* and the same species has been found in turkeys and fowls by Hart (1947). A survey undertaken in Brisbane by Mrs. R. E. Powell (unpublished) has demonstrated Candida-like organisms (apparently doing no harm) in liver, spleen or kidney from 48 of 113 randomly selected human autopsies, and in 16 of 32 animals, including guinea-pig, laboratory rabbit, *Rattus rattus* (L.), *R. norvegicus* (Erxl.) and *Isoodon obesulus* (S. & N.). At least five species of *Candida* have been

* Spindler (1947) believes that *Sarcocystis* is a fungus.

† The names *obesulus* (Shaw and Nodder) and *torosus* (Ramsay) reported in various places in this list almost certainly refer to the one form, which might be regarded as not separable from *obesulus* or as a subspecies, *torosus,* according to one's views on their geographical differentiation (Mack, personal communication).

found, but *C. albicans,* which is the only one certainly known to be pathogenic, has so far been isolated only from humans and the faeces of a laboratory rabbit. It is not known whether there is any relation between human and animal infections.

19. *Sporotrichum schenckii* Matr.—Infections in man have been reported by Robinson and Orban (1951) and Barrack and Powell (1952). Infections of animals, chiefly horses, have been described in other parts of the world, and a case has been recorded of a veterinarian who became infected when treating a horse which was suffering from sporotrichosis. Normally, however, the fungus is associated with vegetation, and the disease follows pricks or scratches from infected thorns or wood splinters.

20. *Nocardia asteroides* (Epp.) Blanch.—Aerobic Actinomycetes have been isolated twice from man, by Goldsworthy (1937) and O'Reilly and Powell (1953), and from lesions in the mouth or lung of domestic and native animals by Mr. G. C. Simmons. There is little doubt of the identity of the human strains with *N. asteroides,* but further work is needed on those from animals, more than one species probably being concerned (Simmons, personal communication).

21. *Actinomyces bovis* Harz.—Infection with anaerobic Actinomycetes occurs in Australia, but not as commonly as the extent of the cattle industry might lead one to expect. Recent work abroad and in Australia (Ludwig and Sullivan, 1952) indicates that at least some strains isolated from human sources are not *A. bovis,* and the opinion is growing that infection is usually, if not always, caused by organisms which normally live as saprophytes in the human mouth.

22. *Trichophyton mentagrophytes* (Rob.) Blanch.—A ringworm. Normal hosts horses and cattle, but infections recorded in many other animals, including guinea-pigs in Brisbane. Transmission to man not infrequent.

23. *Microsporum audouini* Gruby.—A ringworm. Normal hosts dogs. Transmission to man not infrequent.

24. *Microsporum lanosum* Sab.—A ringworm. Normal hosts kittens, puppies, rabbit kittens. Transmission to humans, especially children, not uncommon.

Bacterial Infections.

It will be convenient, from this point onwards, to list the names of the infections rather than of the causative organisms, because the former are generally more familiar, some infections are caused by several related organisms (for example, leptospirosis, salmonellosis), and, when we come to the viruses, generic and specific names are still somewhat imaginative.

25. BOVINE TUBERCULOSIS.—It is well known that tubercle bacilli of bovine origin may infect human beings. These infections are usually, though not always, milk-borne, and are now much less frequent than formerly. Webster (1941) recorded no bovine infections in adults in Victoria since 1924*, and a declining proportion, from one-fourth of all tuberculous infections investigated in children under 14 prior to 1932, to one-tenth nine years later. He stated that the change was "correlated with a striking reduction in tuberculin reactors in herds."

* Derrick (1945) has reported one in Queensland.

26. ERYSIPELOID.—*Erysipelothrix rhusiopathiae* is fairly common in pigs in Australia, and Speight (1951) believes that it is also not uncommon in man, with a strong occupational incidence in those who handle meat at any stage from slaughter to cooking and in the fell-mongering and wool-scouring trades. Lawes *et al.* (1952) have recorded a case of subacute bacterial endocarditis as having been caused by this organism, but infections do not often come to bacteriological examination, so precise information is difficult to obtain.

27. LISTERIOSIS.—Infection with *Listeria monocytogenes* is not infrequent in sheep, but only one case of *Listeria* meningitis in man appears to have been recorded in this country (Stanley, 1948).

28. LEPTOSPIROSIS.—This is a typical animal reservoir infection, usually with an equally typical occupational bias. Infection may be direct, or, more frequently as a result of leptospirae, passed in the urine of infected animals, contaminating water, wet soil or wet vegetation (e.g., sugar cane), and entering the body through abraded skin or mucous membranes.

Johnson (1950) reviewed the leptospiroses of Australia, and listed five species: *Leptospira ictero-haemorrhagiae,* from Queensland, New South Wales and Victoria; *L. australis A* and *L. australis B,* from North Queensland; and *L. pomona* and *L. mitis,* from Queensland and northern New South Wales. Since then, *L. pomona* has been recorded from Victoria by Wellington *et al.* (1951), Graves *et al.* (1951), and Forbes and Lawrence (1952a, 1952b), while Sinnamon and Pask (1952) and Sinnamon *et al.* (1953), in collaboration with the State Laboratory of Microbiology and Pathology, have added three species in North Queensland, namely, *L. canicola, L. medanensis,* and an undescribed species which passes under the temporary name "Celledoni." Still more recently, *L. australis B* and *L. medanensis* have been split into subgroups, so that altogether eleven types of leptospirae are now known in this country.

The animal reservoirs, for which there is direct or indirect evidence so far are:—

Cattle: *L. pomona, L. mitis* (serological).

Pigs: *L. pomona, L. mitis.*

Dogs: *L. ictero-haemorrhagiae, L. pomona* (serological), *L. australis A* (serological).

Introduced rats (*R. rattus, R. norvegicus*): *L. ictero-haemorrhagiae, L australis B* (serological).

Rattus conatus Thomas: *L. australis A, L. australis B.*

Bandicoots (probably *Isoodon obesulus* S. & N.): *L. australis A* (serological).

Perameles nasuta Geoff: *L.* "Celledoni" (serological).

Trichosurus vulpecula Kerr: *L. medanensis* (serological).

The entries marked as serological must be regarded as tentative, because there is considerable serological overlapping between some of the types. Clearly, a great deal remains to be done in this field.

29. RAT BITE FEVER (*Spirillum minus*).—The occurrence of *S. minus* in rats in Queensland was recorded by Derrick and Brown (1936), who also reviewed suspected infections in man. Since then, additional cases have been described by Shallard (1937) in New South Wales, Powell (1939) in Victoria, and Lawrence (1942) in South Australia. The organism is difficult to isolate from human material, and all the cases

recorded rest on clinical evidence only. It would appear, too, that its infectivity for man is usually low, because it is probably not uncommon in our laboratory rats and mice and several people have been bitten, including two by a mouse which had *S. minus* in its blood at the time.

30. RAT BITE FEVER (*Streptobacillus moniliformis*).—Rountree and Rohan (1941) have recorded a fatal infection in a girl who was bitten on the face by a rat in Victoria, Gray and Hoeben (1941) mention an epizootic in laboratory rats and mice in Queensland, and Stephen Williams (1941) has described an epizootic which occurred during a plague of wild mice (*Mus musculus* L.) in New South Wales. His experience was like ours, in that he was frequently bitten by infected mice without ill effect.

31. PLAGUE.—Except in the comparatively rare pneumonic form, infection in man is always an overflow from an epizootic in an animal population. Epidemics occur, when the animals involved are urban rats, and contact with man via the rat flea, *Xenopsylla cheopis* (Roths.), is frequent. There have been two periods when plague has invaded Australia, between 1900 and 1909 and in 1921-22 (Cumpston and McCallum, 1926). In both, it remained strictly urban, and there was no evidence of establishment of ''sylvatic plague'' in native animal populations, as has occurred in some other countries.

32. MELIOIDOSIS.—This infection appears usually to be a disease of rodents in Malaya, where it was first described; but infection in sheep and goats has been found in North Queensland by Cottew (1950), Cottew *et al.* (1952) and Lewis and Olds (1952), and recently in a pig by Lewis and Olds (unpublished). I know of no published account of the disease in man in this country, but, through the kindness of Dr. R. A. Rimington, of the Commonwealth Health Laboratory, Townsville, I have seen the history of a man who lived at Charters Towers, and who died in the Townsville General Hospital. *Malleomyces pseudomallei* was isolated from his blood no less than four times during his illness, so the identity of the infection is beyond doubt.

33. BRUCELLOSIS.—Two species of *Brucella* may infect man in Australia, namely, *Br. abortus* in all States and *Br. suis* in Queensland and New South Wales. Infections are common in cattle and pigs, relatively rare in humans, and direct contact with infected tissues would appear to be a much more important method of infection than ingestion in milk; otherwise it would be difficult to account for the sex and occupational incidence recorded by Derrick and Brown (1950). As infection of milk is common (Lee, 1952), it is necessary to assume also that infectivity for humans is low, and that the disease is seen chiefly in veterinarians, farmers and meatworkers because they may be exposed to massive doses of the organisms.

34. SALMONELLOSIS.—The epidemiology of *Salmonella* infections is a complicated story. Infants are undoubtedly originally infected from older people (perhaps occasionally from contamination of food by vermin), but the infection may then be spread from infant to infant by the hands of those who care for them in institutions (Mackerras and Mackerras, 1949). Infections are also not infrequent in older humans and in various animal populations. In at least *S. typhi*, the parasite population is maintained in human hosts only, and we may suspect that the same could apply to other species of *Salmonella* too. On the other hand, there are innumerable records of humans being infected from animal sources, which may thus be properly regarded as reservoirs.

Actually, the position seems to be, that most of the common species of *Salmonella* have a wide range of hosts, that they can probably maintain themselves in any one host species, but that they can transfer from one to another whenever the opportunity arises. Their behaviour is thus not typical of the animal reservoir infections as a whole.

The species of *Salmonella* recorded from animals in Australia by Atkinson *et al.* (1944-52), Mackerras and Mackerras (1948, 1949), Simmons (1951), Singer and McCaffrey (1950, 1951), Singer and Ludford (1952), Rac and Wall (1952), Simmons (unpublished) and Lee (unpublished) are set out in the following list, which is arranged according to hosts. Most of them have been found also in man.

DOMESTIC ANIMALS.

Cattle: *S. typhi-murium, S. derby, S. potsdam, S. muenchen, S. bovis-morbificans, S. dublin, S. anatum, S. london, S. meleagridis, S. newington, S. orientalis.*

Sheep: *S. typhi-murium, S. derby, S. potsdam, S. cholerae-suis* var. *kunzendorf, S. newport, S. bovis-morbificans, S. meleagridis, S. anatum.*

Horse: *S. typhi-murium, S. bovis-morbificans, S. kottbus, S. newport, S. meleagridis, S. anatum, S. newington.*

Pig: *S. typhi-murium, S. derby, S. chester, S. cholerae-suis* and var. *kunzendorf, S. paratyphi C, S. bovis-morbificans, S. muenchen, S. newport, S. enteritidis, S. anatum, S. give, S. chester, S. worthington.*

Dog: *S. typhi-murium, S. derby, S. chester.*

Cat: *S. typhi-murium, S. bovis-morbificans, S. cambridge.*

Guinea-pig: *S. typhi-murium, S. blegdam, S. enteritidis.*

Laboratory rabbit: *S. typhi-murium.*

Laboratory mice: *S. typhi-murium, S. enteritidis, S. blegdam.*

Fowl: *S. typhi-murium, S. derby, S. chester, S. saint-paul, S. bredeney, S. oslo, S. oranienburg, S. bovis-morbificans, S. bonariensis, S. bareilly, S. muenchen, S. newport, S. pullorum, S. cambridge, S. anatum, S. london, S. meleagridis, S. give, S. lexington, S. newington, S. champaign.*

Duck: *S. typhi-murium, S. derby, S. bovis-morbificans, S. anatum, S. give.*

Turkey: *S. typhi-murium.*

Pigeon: *S. typhi-murium.*

Sparrow*: *S. pullorum.*

VERMIN.

Rattus norvegicus (Erxl.): *S. typhi-murium, S. chester, S. paratyphi C., S. bovis-morbificans, S. meleagridis, S. adelaide.*

Mus musculus (L.): *S. derby, S. bovis-morbificans, S. orientalis.*

Periplaneta americana (L.): *S. bovis-morbificans.*

Nauphoeta cinerea (Oliv.): *S. typhi-murium.*

MARSUPIALS.

Isoodon obesulus (S. & N.): *S. bonariensis.*

Wallabia dorsalis (Gray): *S. meleagridis, S. anatum.*

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* Placed here for convenience.

Reptilia (Fam. Agamidae).

Amphibolurus barbatus (Cuv.): *S. chester, S. birkenhead, S. muenchen, S. bonariensis, S. adelaide, S. rubislaw, S. waycross.*

Physignathus lesueurii (Gray): *S. adelaide.*

Chlamydosaurus kingii (Gray): *S. rubislaw.*

35. anthrax.—Seddon (1948) gives the central districts and County of Cumberland in New South Wales as the chief enzootic centres of anthrax in Australia, with minor areas in Victoria. It is commonest in sheep, with some cases in cattle and pigs. Few infections in man have been notified in recent years, but a local practitioner has informed me that he has recently seen two in central New South Wales. Formerly, cases were also associated with the use of some imported shaving brushes.

36. clostridal infections.—These are scarcely to be classed here, for, although *C. tetani* and other species normally live in the intestine of horses and some other animals, the rôle of the animal in the chain of infection is to enrich the soil, in which the organisms may live for a very long time, and from which they may enter wounds and abrasions. Gas gangrene is now rare in man, but tetanus is not very infrequent, particularly in Queensland. It may be noted that horses and sheep are just as susceptible in infection of wounds with tetanus bacilli as are human beings, and sheep have their own group of diseases caused by other Clostridia.

Rickettsial Infections.

Apart from epidemic typhus, which was brought to Australia in the early days of settlement, but did not become established, the four rickettsial infections which are now known here are typical animal reservoir infections, in that man is an accidental intruder into a cycle with which he has normally nothing to do.

37. murine typhus.—This disease was discovered by Hone (1922) in Adelaide. He suspected that it came from rats or mice, and it is now well known, chiefly from work in the United States, that *Rickettsia typhi* is a normal parasite of urban rats, which is transmitted from rat to rat by fleas, lice and mites, and occasionally from rat to man by *Xenopsylla cheopis* (Roths.), although the exact mechanism of transmission is not yet understood. A few cases occur almost every year in Australia, chiefly among storemen, grocers and others whose occupations expose them to special risk.

38. scrub typhus.—The ecology of *Rickettsia tsutsugamushi* is similar to that of *R. typhi,* but the reservoirs are bush rodents, the vectors Trombiculine mites, and the intruders are those people whose occasions take them into the fringe of the jungle in Queensland from Mackay northward. Heaslip (1941), chiefly on evidence from serology and mouse inoculation, considered that the reservoirs were *Rattus conatus* Thomas, *R. assimilis* Gould, *Melomys littoralis* (Lönn.), introduced rats, and the bandicoot, *Isoodon torosus* (Ramsey). On epidemiological grounds, he believed the vector to be *Trombicula deliensis* Walch. Southcott (1947) obtained serological evidence suggesting that possibly the pied currawong, *Strepera graculina* (Shaw), might also be a reservoir. Kohle *et al.* (1945), in New Guinea, provided definite proof by isolating Rickettsias from *Rattus concolor browni* (Alston) and *Trombicula deliensis,* but could not find evidence to support the

suggestion that bandicoots were susceptible to infection. Clearly, a good deal of precise work is needed to clarify the situation in Australia.

39. TICK TYPHUS.—Andrew, Bonnin and Williams (1946) described a disease in North Queensland, which they had strong inferential grounds for believing to be a form of tick typhus, and similar cases have been reported in North Queensland by Brody (1946) and South Queensland by Streeten *et al.* (1948). The Rickettsia isolated from the North Queensland cases proved to be related to, but distinct from, those causing tick typhus in other parts of the world, and has been named *Rickettsia australis.* Fenner (1946) concluded on serological evidence that probable reservoirs were *Isoodon obesulus* (S. & N.), *Perameles nasuta* Geoffroy, *Trichosurus vulpecula johnstonii* Ramsey, *Aepyprymnus rufescens* (Gray) and *Uromys sherrini* Thomas. The vector is suspected to be the common *Ixodes holocyclus* Neum., but no direct evidence has yet been obtained against this or any other tick.

40. Q FEVER.—*Rickettsia burneti* behaves in many ways very differently from other species of the group, so differently that several authors place it in a different genus, *Coxiella.* From the present point of view, the most striking difference is its extraordinary wide host range, both in vertebrates and in ticks. In Australia, cattle are frequently infected, and are the major source of infection in man. Among native mammals, *R. burneti* has been isolated from *Isoodon torosus* (Ramsey); antibodies have been found in captured *Aepyprymnus rufescens* (Gray), *Hydromys chrysogaster* (Geoffroy) and *Rattus lutreolus* (Gray); while *Trichosurus vulpecula* (Kerr), *Rattus assimilis* (Gould), *R. conatus* Thomas, *R. culmorum* Thomas and *Melomys littoralis* (Lönn.) (and also *H. chrysogaster* and *R. lutreolus*) have been experimentally infected in the laboratory. Ticks, in which infection has been found in nature or produced experimentally, are *Haemaphysalis humerosa* W. & N., *H. bispinosa* Neum., *Boophilus annulatus microplus* (Canest.), *Ixodes holocyclus* Neum., *Rhipicephalus sanguineus* (Latr.) and *Ornithodorus ?gurneyi* Warburton. Evidence of transovarial infection has been found in *H. humerosa,* and also in ticks in other parts of the world, so it seems possible that at least some species may serve as a continuing reservoir, without intervention of infection in a vertebrate.

Evidence of a native *Isoodon-Haemaphysalis* cycle has been found on Moreton Island, South Queensland; but it is not known whether the infection was originally native to Australia, whether the native animals acquired it from cattle or vice versa, nor how human beings become infected. Neither Arthropod vectors nor infected milk appear to be significant in Queensland, and close contact with infected cattle seems usually to be essential. Derrick (1953) has reviewed the literature, and discussed these problems in detail.

VIRAL INFECTIONS.

41. PSITTACOSIS.—This is an infection mainly of parrots and their allies, which Burnet (1935, 1942) and Tremain (1938) demonstrated to be quite widespread in Australia, the species found infected being *Trichoglossus chlorolepidotus* (Kuhl), *T. moluccanus* (Gmélin), *Kakatoë roseicapilla* (Vieillot), *Leptolophus hollandicus* (Kerr), *Aprosmictus scapularis* (Licht.), *Polytelis anthopeplus* (Lear), *Platycerus elegans* (Gmélin), *P. eximius* (Shaw), *P. adscitus* (Latham), *Barnardius zonarius* (Shaw), *B. semitorquatus* (Quoy & Gaimard), *B. barnardi* (Vigors & Horsfield), *Psephotus haematonotus* (G.), *Melopsittacus undulatus* (Shaw), and the finches, *Poephila gouldiae* (G.) and *P. acuticauda* (G.).

Humans are infected by breathing infected dust from captive birds and their cages. Tremain gives references to cases recorded to 1938, all in Victoria, and Yeatman and McEwan (1945) have described a later outbreak in South Australia.

42. MURRAY VALLEY ENCEPHALITIS.—This infection is related to Japanese B encephalitis. The natural reservoirs are birds, the vectors presumably mosquitoes, and secondary hosts are horses and man, while antibodies have also been found in dogs, foxes and *Trichosurus vulpecula* (Kerr). No evidence of infection was found in sheep, cattle or pigs (Anderson *et al.*, 1952). Among the sixteen species of water birds and nine of land birds, in which neutralising antibodies have been detected, the following showed the highest incidence: *Notophoyx novae-hollandiae* (Latham), *Nycticorax caledonicus* (Gmélin), *Microcarbo melanoleucus* (Vieillot), *Phalacrocorax carbo* (L.), *Lobibyx miles* (Boddaert), *Kakatoë sanguinea* (G.), *Grallina cyanoleuca* (Latham) and *Gallus domesticus* L.

The extremely interesting epidemiological problems presented by M.V.E. have been reviewed by Burnet (1952), Miles and Howes (1953) and Mackerras (1953).

43. CONTAGIOUS ECTHYMA.—It was long suspected by people in the grazing industry that ''scabby mouth'' could be transmitted from sheep to man. This was proved to be correct by Pask *et al.* (1951), but they found also that human skin did not provide as good as environment for the virus as the skin of the sheep.

44. CAT SCRATCH DISEASE.—Inglis and Tonge (1950) described a curious granulomatous infection of lymph glands in Queensland. About the same time, workers in Europe described a similar condition, which, in many instances, followed scratches by cats. The causal organism is unknown, but is suspected to be a virus. Tonge *et al.* (1953) have now obtained evidence that their infection is the same as ''cat scratch disease'', though the association with cats has not been as close as in the European cases.

Infections Not Included.

The following have been excluded from the list, for the reasons indicated:—

Parasites, such as *Taenia saginata* Goeze, which have an alternation of hosts, of which man is specifically one; these do not comply with the essential condition that the parasite population is independent of the human population.

Introduced infections, such as African trypanosomiasis, Japanese schistosomiasis, *Diphyllobothrium latum* (L.), *Trichinella spiralis* (Owen) and others, which have not become established here.

The *Ascaris* of the pig, because it has been shown to be specifically distinct from the *Ascaris* of man.

Balantidium coli (Malm.), which has been found in pigs in Queensland and Victoria (Seddon, 1952), but does not so far appear to have been recorded from man in this country.

Benign lymphocytic choriomeningitis, which was recorded by Parry (1951); the name was used in a general rather than a specific sense, and there is no evidence that the L.C.M. virus was concerned.

The condition known as ''cow pox'' in Australia, which is transmissible to man, but of which the etiology is still obscure (Seddon, 1952).

PART II. SOME PROBLEMS IN ECOLOGY.

General Considerations.

When we look at the data in Part I., the first fact that impresses us in that here is a formidable array of infections. That is true, but the impression needs qualification. Except for the Salmonella infections, which man may be said to share with the animals, and which can spread in human populations; and for the leptospiroses in certain limited geographical areas; and for plague, when there is a severe epizootic in a large urban rat population; the majority of animal reservoir infections are uncommon, and many of them are no more than clinical and zoological curiosities. Sporadic, scattered, apparently unrelated appearance in man is, in fact, a normal characteristic of this group.

The second characteristic that impresses us is related to the first, and is that, in the majority of these infections, man forms no part of the ecological niche which the parasite normally occupies. Infection in him is an overflow into marginal territory, and, just as with locusts, birds or mammals in marginal territories, the overflowing populations usually die—although they may sometimes kill their strange host in the process*. This phenomenon is well known, and man is often spoken of as an intruder. It is, however, necessary to emphasise it, because it has one very important practical consequence, namely, that controlling these infections in man in no way influences the effective parasite population; if we wish to do that, we must control them in the animal hosts, which is often a much more difficult task.

The third phenomenon that impresses us is that the reaction provoked by a parasite often differs markedly in its principal and casual hosts. It is a question of adaptation. Over a long evolutionary association, most parasites and hosts have arrived at a nicely adjusted mutual balance, so that they now live together in moderate amity. It is rarely beneficial to a parasite to kill its host, unless it needs to do so to achieve dispersal (as, for example, in the Myxosporidia). It has frequently followed that, as adaptation to particular hosts has become more and more perfect, so the ability to infect other hosts has decreased, and the parasites have become progressively more host specific. A well-balanced, highly specific host-parasite association is the normal climax situation. Some parasites, however, have remained sufficiently plastic to multiply in a variety of hosts; and in these we frequently find that the relationship with the principal host is one of well balanced tolerance, whereas there is decided discord with the occasional hosts.

There are two stages in this adaptive process. The first is a progressively increasing ability of a parasite to invade a foreign host. It may be illustrated by the worms. At one end of the scale, the cercariae of avian Schistosomes can enter human skin, but they go no further, and quickly die. The hookworms of the dog also cannot usually penetrate beyond the skin of man, but they persist, producing creeping eruption, although they rarely reach the intestine. The *Ascaris* of the pig goes further; the larvae hatch in the intestine and

* As with other animals and plants in marginal territory, the occasional ones that do not die may become adapted to the new environment, isolated from their parent populations, and so become the founders of new species of parasite in a new host. These casual infections are thus of fundamental biological importance as well as practical interest, but this side of their story is not relevant to the present discussion.

pass from the gut to the lungs, where they may produce pneumonitis, but they die when they reach the alimentary tract again. Finally, man is as good an intermediate host of *Taenia echinococcus* as the sheep or the wallaby.

The second stage comes when the parasite can establish itself in its normal tissue habitat. The new host reacts to the intrusion and disease is the usual result. This is a somewhat dangerous situation, because we have reservoirs, which are perfectly well and therefore unnoticed, spreading disease to an unsuspecting human population. Relapsing fever, the rickettsioses and leptospirosis are classical examples. In this stage, severity of illness is a cardinal sign of incomplete adaptation. Mildness, on the other hand, may indicate, either that the parasite has only acquired a slender hold on its host, or that mutual adaptation is well advanced. Duration of infection, not of illness, should differentiate between the two, and we may therefore suspect that the milder rickettsioses and leptospiroses may represent incomplete adaptation as well as the severe ones.

When we look for examples to illustrate the steps in this process of adaptation, we find them more readily in the malaria parasites of vertebrates than in the infections recorded here. *Plasmodium falciparum* may kill fully susceptible Europeans and *P. vivax* give them a very unpleasant experience; but native races, who have lived with them for many generations, show a considerable tolerance to both species. The malaria of monkeys is usually mild; but transfer *P. knowlesi* to a strange simian host, and it becomes as severe as *P. falciparum* in northern Europeans, a fact that has been made use of in experimental malariology. Incidentally, when *P. knowlesi* is inoculated into man, a still stranger host zoologically, it cannot maintain its hold, and the result is a very mild and transitory infection. In birds, which are also a recent, highly evolved group, infections vary from severe to very mild, and there is the added phenomenon, not recorded so far in the mammals, that the exoerythrocytic stages may sometimes kill, as well as those in the blood cells. By contrast, the reptiles, in which the host-parasite relationship must be presumed to have developed over long geological periods, show the most perfect tolerance. It is often possible to find abundant parasites of various genera in the blood of reptiles which are lively and active and show no signs of ill-health whatever. The parasite population is high, and its chances to spread from host to host are at a maximum. This is the climax situation, of which I spoke earlier.

The practical consequence of all this is that we look for *disease* in our patients, but *infection* in the reservoirs. In the classical animal reservoir infections, the carrier state is normal in the reservoir, but does not occur, and need not be considered, in the casual human victim, a conclusion which also follows from the second of the general characteristics stated earlier.

We come now to a fourth consideration, which is by no means limited to this nor to any one field of biology, and that is that there are important exceptions to the classical picture which I have endeavoured to present above.

The *Salmonella* infections are an exception, and I have already endeavoured to indicate this by expressing the opinion that they are *shared* by man and animals, there being little indication of a principal host-casual host relationship. Indeed, they seem to be equally imperfectly adapted to all hosts, and one may see acute enteritis in all, lizards as well as birds and mammals. Conversely, the carrier state can be found in all, too, and we know nothing of the reasons why the same species of *Salmonella* in the same species of host, whether it be a human baby or an *Amphibolurus,* may at times appear to be quite harmless and at others be fatally pathogenic. Again, there are exceptions: *S. typhi* is almost exclusively a parasite of man, *S. enteritidis* (in this country) of rodents, and *S. pullorum* of birds, and some hosts seem to harbour more species of *Salmonella* than others; but the table of infections in Part I indicates clearly enough the broad truth of the statement.

The second group of exceptions is a particularly interesting one. An infection, which normally smoulders quietly in the principal hosts, may, apparently quite suddenly, show increased infectivity (and sometimes virulence), and produce a widespread epizootic, with a consequent increased overflow into the human population. Plague is the classical example, epidemics in human populations being always preceded and accompanied by a fatal epizootic in urban rodents. Burnet has described a natural epizootic of psittacosis in Australian parrots, but the contacts of these birds with humans in the bush are few, and there does not appear to have been any significant overflow. On the other hand, there is considerable evidence that an appreciable incidence of M.V. encephalitis in humans is seen only when a rather rare set of special circumstances has led to widespread subclinical infection in the avian population. In the view of Miles and Howes, the essential condition is exceptionally early rain in the northern rookeries of water-birds, leading to production of two broods in the year and early dispersal of young infected birds through the southern parts of the country at a time when mosquitoes are active. Silent epizootics in local birds follow, and then overflow into the human population. As less than one per cent. of infected humans show clinical signs, the mass of infection must be very considerable before a clinical epidemic becomes apparent.

With this background of information, incomplete, but still sufficient to give us a fair appreciation of the situation, we may consider what may be done about it. I have always held, and time has not altered my views, that the true approach to any problem in economic or medical biology is through a full understanding of the problem. In the present instance, the frequency of infection in man depends primarily on the frequency of effective contacts, direct or indirect, between the human and animal populations, and we must examine this aspect before proceeding further.

Frequency of Infection in Man.

The frequency of infection in man depends on five sets of factors, of which the last three interact with one another.

1. Spread within the human population.

When man to man infection can occur, factors other than those relating to contact with the animal population come into play, and the disease ceases to show true animal reservoir characteristics. *Salmonella* infections are the most important example in this country, yellow fever in tropical America and Africa. Indeed, it was not realised that yellow fever had an animal reservoir, until it was found that the virus could not be exterminated by preventing its spread within human populations. In Q fever, the sick may occasionally infect the healthy, but that is not part of its usual epidemiology.

2. THE DOSAGE OF INFECTION.

We know practically nothing about the number of organisms needed to produce recognizable infection in man in any of the diseases listed in Part I. Nevertheless, there is a certain amount of indirect evidence. The infective dose of worms would appear to be small—probably a single Ancylostome larva will produce a single line of creeping eruption—and it seems likely that it is small, too, in leptospiral and most rickettsial infections. By contrast, there is evidence, mentioned earlier, that the infective dose in brucellosis is probably large. This factor influences the availability of particular pathways of infection; but it does not concern us otherwise, because transmission is measured automatically by infective doses, in that it is assessed by palpable infection in man. We should, however, when examining a possible source of infection, remember always to ask ourselves: is it adequate? And we often cannot give an answer.

3. THE PATHWAY OF INFECTION.

These may be tabulated, with illustrative infections, in order of increasing length of the path. Broadly speaking, infections with more direct transmission usually come from domesticated animals, contaminative ones from vermin, and those with an Arthropod vector from native animals.

(*a*) By *contact* with the host or its products: ringworm, rat bite fevers (2), erysipeloid, brucellosis, anthrax, ? Q fever, contagious ecthyma, ? cat-scratch disease.

(*b*) By *ingestion* of the host or its products: spargana, bovine tuberculosis (milk), salmonellosis, brucellosis (milk, rare), Q fever (milk, rare).

(*c*) By *inhalation* of infected dust or droplets: ? moniliasis, bovine tuberculosis (rare), Q fever, psittacosis.

(*d*) By *contamination*: Trichostrongyles, hydatid, *Hymenolepis nana,* salmonellosis.

(*e*) From *external environment,* including long range contamination: creeping eruption, liver flake, bathers' itch, leptospirosis, clostridial infections.

(*f*) By an *Arthropod vector*: *Dipylidium caninum* (by ingestion), *Hymenolepis diminuta* (by ingestion), plague murine typhus, scrub typhus, tick typhus, M.V. encephalitis.

This tabulation is by no means complete, chiefly because the pathway is unknown or but dimly perceived in several of the infections which are listed in Part I. Nevertheless, the sort of knowledge which is set out here is often of the greatest value in planning measures of control, and the gaps in our knowledge are therefore a stimulus to further endeavour.

4. THE PORTAL OF ENTRY.

This is largely determined by the pathway of infection. Most infections have only one portal of entry, but a few have two or more, and infectivity may vary markedly by the different available routes. Thus, *Rickettsia burneti* is much more infective by the respiratory portal than by any other, and it seems possible that *Brucella* may infect more readily through the skin than the digestive tract. This is a case in which dosage and portal are difficult to disentangle in the present state of our knowledge.

5. ASSOCIATION BETWEEN HOSTS.

It is a truism to say that, the higher the interacting populations, and the closer the association between them, the greater the chances that infection will spread from one to the other, but it is still profitable to examine the position. So far as man is concerned, the domestic animals (sheep, cattle, fowls, etc.) on which he depends, and the vermin (rats and mice) which infest his settlements, are naturally the most important; canefield rats spread more leptospirosis than bush rats spread scrub typhus, even though closely related species may be involved; cage birds disseminate more psittacosis to man than wild birds; and so on. Infections which are transmitted by a wide-ranging vector (e.g. mosquito-borne encephalitis) may be an exception to this rule, for their frequency in man depends on frequency of attack by the vector, not on human contacts with the reservoir. Even in encephalitis, however, there is probably a chain of infection from water-birds to birds which live near the habitations of man, and from them, probably by a different vector, to humans. Mr. Sutherland has told me of another interesting chain. Dairy farmers keep pigs to consume the surplus skim-milk, and so turn it to profit. The pigs are reservoirs of leptospirae, which spread from them to the cattle, and thence to man. Thus, infection in both bovine and human depends, to a degree, on sound farming practice!

In the tabulation below, all the infections listed earlier from animals are included, though it does not necessarily follow that they are likely to pass from a given host direct to man—he is not, for example, in much danger from spargana in frogs or Salmonellas in lizards! Moreover, it cannot be taken that species in different hosts are necessarily identical; in some instances, for example *Sarcocystis,* we simply do not know. A question mark indicates that infection in the host group has not been proven. In spite of these imperfections, it is clear that, at least in the number of different kinds of infections, the sequence is very much as one would expect from what has been said above.

DOMESTIC ANIMALS.

Trichostrongyle worms, creeping eruption, Habronema, hydatid, dog tapeworm, spargana; liver fluke.

Toxoplasma, Sarcocystis, nocardiasis, actinomycosis, ringworm (3 species).

Bovine tuberculosis, erysipeloid, listeriosis, leptospirosis, melioidosis, brucellosis, salmonellosis, anthrax, clostridial infection.

Q fever.

Contagious ecthyma, encephalitis, ? cat-scratch disease.

VERMIN.

Rat tapeworm, mouse tapeworm, spargana.

Sarcocystis, moniliasis.

Leptospirosis, rat-bite fever (2 species), plague, salmonellosis.

Murine typhus.

NATIVE ANIMALS.

Dingo: Hydatid.

Rodents: Leptospirosis; scrub typhus, tick typhus, Q fever.

Marsupials: Hydatid, spargana; Sarcocystis, moniliasis, nocardiasis; leptospirosis, salmonellosis; ? scrub typhus, tick typhus, Q fever; encephalitis.

Birds: Bathers' itch; Toxoplasma; ? scrub typhus; psittacosis,, encephalitis.

Reptiles: Spargana; Sarcocystis; salmonellosis.

Frogs: Spargana.

The part to be played in the control of these diseases by veterinary workers, meat and food inspectors, and those whose duty it is to control vermin, is obvious; but the native mammals and birds present a special and very interesting problem. Shorn of rarities and infections of doubtful validity, they are primary reservoirs of at least four types of *Leptospira,* scrub typhus, psittacosis, M.V. encephalitis, almost certainly tick typhus, and possibly Q fever. It remains to examine how our knowledge of them can be enlarged.

Development of Future Research.

On the present level of knowledge, we can do a great deal to prevent or ameliorate the animal reservoir infections. I have already mentioned the part that can be played by veterinarians in controlling infection in domestic animals, and meat and food inspectors in preventing it from reaching the human consumer, to which should be added the valuable progress that has been made in pasteurising urban milk supplies. Vermin control still leaves much to be desired; nevertheless, no one who has known Brisbane thirty years ago and to-day could deny that substantial progress has been made in this field, too. The occupational bias of some infections like leptospirosis in cane-workers and Q fever in meat-workers, has been clearly recognized (indeed, it may have been over-emphasised in some cases), and considerable sums are paid out every year in compensation—although this is a form of amelioration we would all be glad to see become less necessary. Methods of controlling contaminative infections have been improved, though not always applied. We can immunize against tetanus. We cannot yet control bush rodents or Trombiculine mites, but McCulloch developed a simple way to use dibutyl phthalate as a barrier between the mite and its casual human host—and now chloramphenicol has robbed scrub typhus of most of its terrors.

Progress has, indeed, been notable; but, as in every field of research, it has also led to the definition of problems which still need to be studied. These involve different kinds and levels of research, and I think that they can be arranged in a logical sequence, although some degree of overlapping and integration will certainly be desirable in practice. In all of this, I am thinking, as I said earlier, primarily of the infections that reside in our native animals, for I believe that these now merit most attention.

1. Primary microbiological investigations.

The first step, which is essentially a task for the microbiologist, is to discover whether there are any still unrecognized infections that attack man. I have already mentioned the recent discovery of five leptospiral infections that were previously unknown in Australia. There may be more, and there may be new Rickettsias and viruses that have escaped notice in the past. At the same time, we need to improve the methods of identifying the known infections; there is, for example, a good deal of evidence that some cases of scrub typhus are not recognized, because we lack a sufficiently precise and delicate method of identification. I do not think that there is room in this for clinical investigation, for there is so much variability and overlapping in the manifestations of these infections in the human host, that clinical analysis can only point a wavering and uncertain finger at their identity. Another important task under this head is to discover whether the M.V.E. virus still persists in Australia, and if so, where. Is Miles correct in suggesting that the infection is still smouldering in the far north? Techniques recently developed in the Walter and Eliza Hall Institute, Melbourne, may help us to answer this question.

2. THE SEARCH FOR RESERVOIRS AND VECTORS.

In this phase of the work, the zoologist begins to appear as an essential member of the team: first, to collect animals in the field—Arthropods as well as vertebrates—for the microbiologist to examine; and second, to provide accurate identifications of the species studied. The normal way to meet both needs would be to have a good field man, satisfactory methods of preservation, and a sound liaison with systematists in museums. I feel, however, that this is not enough, and that a great deal would be gained if the field worker himself had a good systematic knowledge of the groups with which he was working.

This team would accumulate still more facts of the kind that are described in this paper, and they are needed. But it could go further; it could provide basic information about the incidence of infection in different reservoir species, which at present is almost completely lacking, and it could demonstrate chains of infection, like those mentioned on an earlier page. Sideline investigations may also well be profitable, and the behaviour of parasites in strange hosts may throw unexpected light on more homely phenomena. That is why we are so interested in the curious problems of how insectivorous and dandelion-eating Agamids acquire their *Salmonella* infections, and whether they have them when not in contact with man or his domestic stock.

3. HABITAT STUDIES.

The collaboration between the microbiologist and zoologist is now left behind and the task becomes purely one for the field ecologist. Too little work of this kind has been done in Australia, the most useful so far, from our point of view, being McDougall's (1944) study of canefield rodents in North Queensland.

I have been very impressed with the effect that small changes in the environment, produced even by sparse settlement, have had on many native animals; they have vanished away from places where they were once common. My own experience has been mainly with insects, but the same has happened to mammals and birds. I feel, therefore, that equally small changes, provided they were of precisely the right kind, might drive away some of our reservoir rodents and bandicoots from the places where we do not want them. These could only be revealed by careful, detailed habitat studies. Equally, it might be demonstrated that we cannot attack the reservoirs in this way; but it is certainly worth trying, for the methods of control at present available are not highly efficient, and the general knowledge obtained would in any case not be wasted.

I have a strong aversion to the extermination of any of our native fauna—too much of it is disappearing already—and it seems to me that a safe balance between control and extermination can only be achieved through such studies as I have indicated here.

4. POPULATION STUDIES.

These carry the ecological investigations to their logical conclusion. Again, McDougall (1946) has made a beginning, and he has demonstrated periodic restlesness and local movements of canefield rodents, which seem to me to be particularly well adapted to disseminating infection far and wide. We need to know more about happenings of this kind. But the matter goes further than that, for, in the words of Elton (1942): "Animal population dynamics . . . promises to become the fundamental science upon which pest control and protection from animal diseases will be based." We should therefore not lag behind in developing this field.

CONCLUSION.

As in every branch of knowledge, we are advancing from the simple to the complex, from the plain observations of the field naturalist to a highly specialised science. We have made a beginning by defining our problems; we are in stage one of development, with excursions into stage two. Whether we ourselves will go further and attempt to follow them through to their logical conclusion, I do not know; but someone, somewhere, will certainly do so, and will complete a story that is still only half written.

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CONTRIBUTIONS TO THE GEOLOGY OF BRISBANE.

No. 2. The Structural History of the Brisbane Metamorphics.

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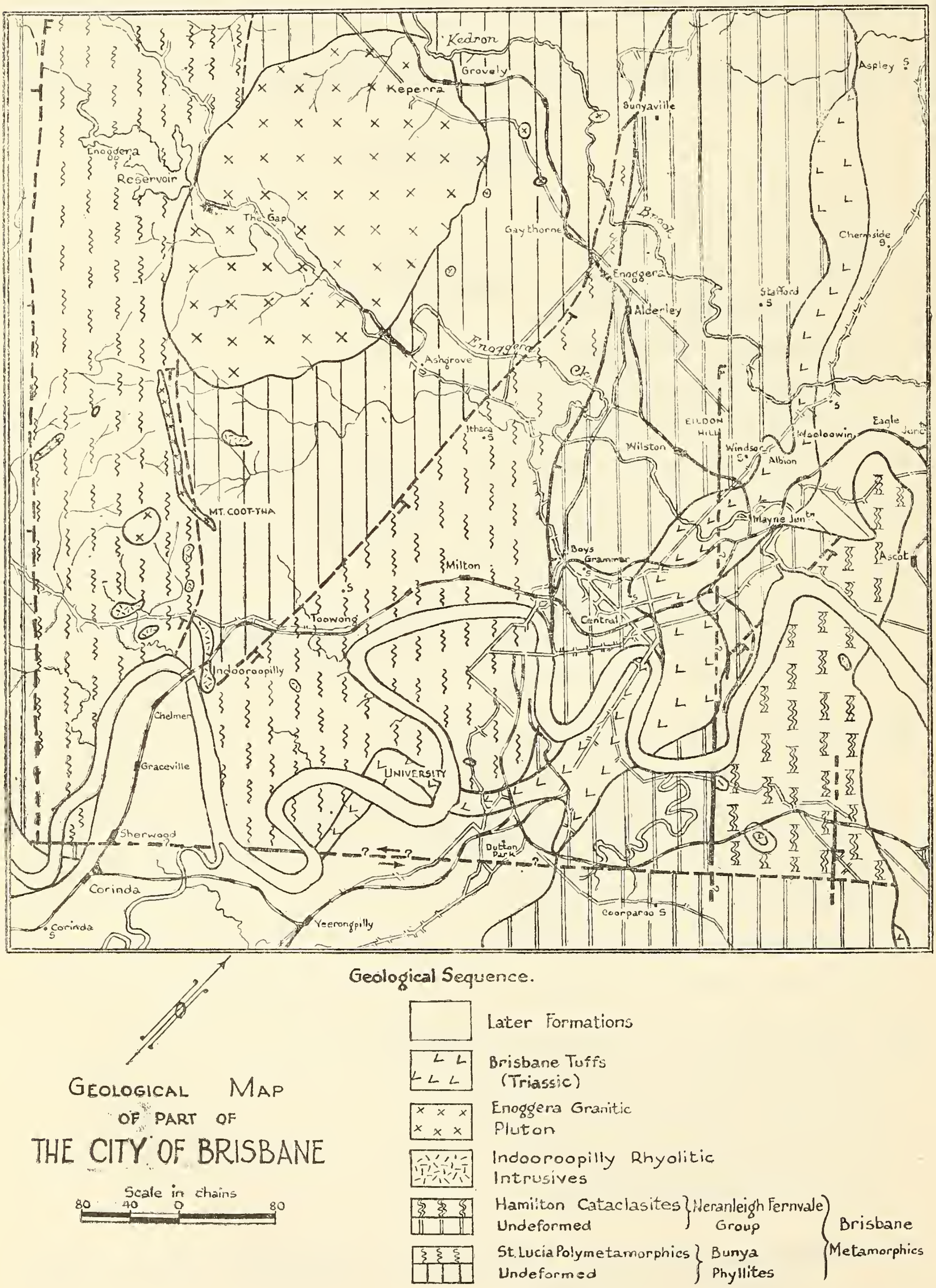
CONTENTS.

I.—INTRODUCTION.

In the past, the history of the Brisbane Metamorphics has been, in our opinion, grossly over-simplified. It is our aim, in this contribution, to show that by the end of the Palaeozoic era, the Brisbane Metamorphics had undergone a protracted and complicated history of tectonic, metamorphic and igneous events. But although the story as we now tell it is much more elaborate than earlier versions we feel



GEOLOGICAL MAP OF PART OF THE CITY OF BRISBANE that it may still be an over-simplification and that more detailed studies by future workers will likely reveal a history fascinating in its complexity.

A great deal has been written about the Brisbane Metamorphics but the one all-important contribution that has been made (and one which includes references to all earlier work) is the paper by Denmead (1928), entitled "A Survey of the Brisbane Schists".

Denmead interpreted the Metamorphics as a conformable succession consisting of four series, namely—the Greenstone Series (basic volcanics, &c.), the Bunya Series (phyllites, &c.), the Neranleigh Series (greywackes, &c.) and the Fernvale Series (jaspers, &c.). He pointed out that one group of rocks, the "Hamilton Schists," did not fit neatly into his succession and might have been introduced by overthrusting, but he mapped it as part of his Bunya Series. He named the "Indooroopilly anticline" as the dominant structural feature within the area.

Little of importance on the subject has been published since Denmead's paper, although valuable, but as yet unpublished, work has been done outside the city limits by R. T. Mathews on the Greenstones to the north and D. J. Belford on the Neranleigh Series to the south.

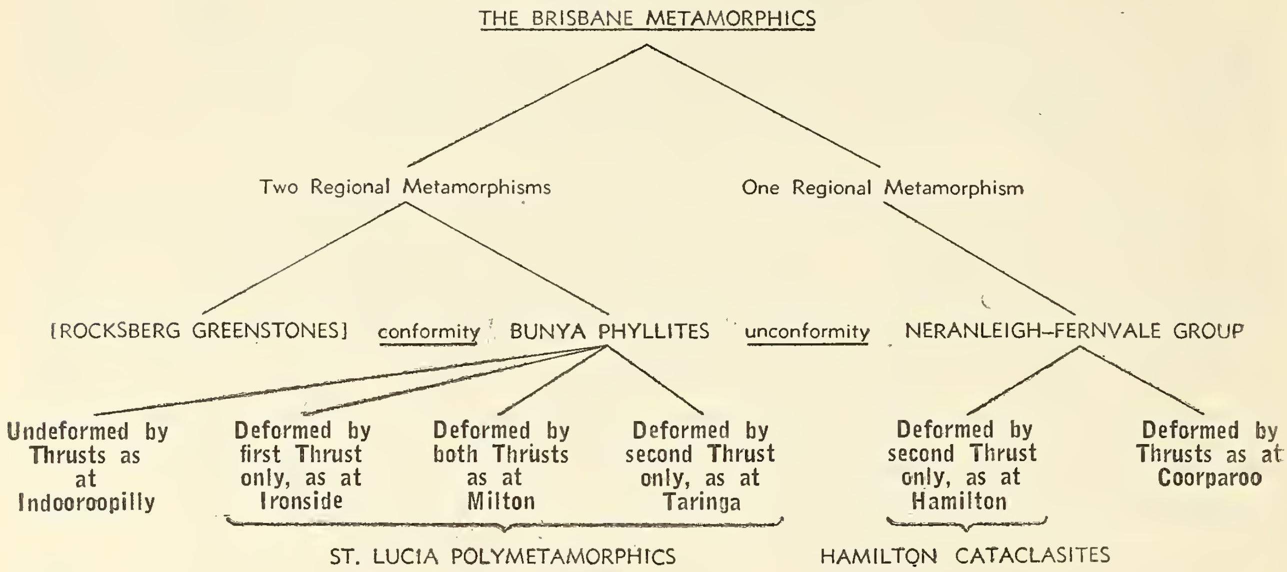
In our Contribution No. 1 to the Geology of Brisbane (Bryan and Jones, 1950) we made some adjustments to the serial nomenclature of the Brisbane Metamorphics to bring it into harmony with the recently introduced stratigraphical code. We have also published a geological map of the area and accompanying Explanatory Notes in which we briefly anticipated some of the main points of the present contribution (Bryan and Jones, 1951).

II.—THE COMPONENT FORMATIONS OF THE BRISBANE METAMORPHICS.

(A) General Statement.

The picture presented by the Brisbane Metamorphics is a very variegated one. This is due to the large range of lithological types involved and to the several different degrees to which these have been metamorphosed. The diversity of the original material might be expected to have resulted in differences of kind and in apparent differences of intensity of the metamorphic products even if only one uniform metamorphism has been experienced, and further variety would have been introduced as a result merely of the variation of intensity of this one metamorphism from place to place. But the complexity of rock types is so pronounced that it would be unreasonable to expect such a relatively simple explanation to fit all the facts, and we were early forced to the conclusion that only by invoking the sequential and varied effects of multiple metamorphism could an hypothesis adequate to explain all the varied features of the Brisbane Metamorphics be developed.

The following diagram by setting out concisely our views on this matter will, it is hoped, assist the reader in following the argument to be presented:—



The arrangement adopted above differs in some respects from that set out in our earlier statement (1951). In particular the St. Lucia Polymetamorphics are now treated as the deformed representatives of the Bunya Phyllites, and the Hamilton rocks (here called the Hamilton Cataclasites) are now regarded as definitely distinct from the St. Lucia Polymetamorphics and as the deformed equivalent of the Neranleigh-Fernvale Group.

(B) The Rocksberg Greenstones.

The lowest series in the structural sequence is that formed by the Rocksberg Greenstones. These are in all essentials identical with Denmead's Greenstone Series. According to Mathews (1950) "The Rocksberg Greenstones are a series of metamorphosed basic rocks, possibly originally olivine basalts and related rocks forming the core of an anticline . . . [they] have been subjected to at least two periods of metamorphism . . . post-dating the orogeny. . . . . The greenstones are shown to be a disequilibrium assemblage, with anomalous mineral associations which make it difficult to determine the metamorphic grade, but it is not thought that the rocks rise above the chlorite zone."

The only analysis available is that of one of a group of rocks which Mathews described as "Normal rocks with a mosaic of albitic plagioclase grains together with actinolite, epidote, minor chlorite and sphene or leucoxene." The analysis is as follows:—

	Per cent.		Per cent.
SiO_2	50·65	TiO_2	0·86
Al_2O_3	11·47	CO_2	0·10
Fe_2O_3	4·11	P_2O_5	0·17
FeO	5·75	NiO	0·03
MgO	11·65	MnO	0·18
CaO	7·74	H_2O+	3·21
Na_2O	3·07	H_2O-	0·55
K_2O	0·68		
		Total	100·22

The Rocksberg Greenstones are, in their upper part, interbedded with the lowest members of the Bunya Phyllites which comformably succeed them. There is only one small and inconspicuous outcrop of the Greenstones within the area of Greater Brisbane, namely, on the road from Bald Hills to Brighton.

C. The Bunya Phyllites.

These succeed the Rocksberg Greenstones as a strictly conformable sequence, for Mathews has shown that at Petrie and other places to the north of Brisbane the lowest members are interbedded with the uppermost Greenstones to form a transitional series. In Brisbane itself the Phyllites show evidence of having suffered regional metamorphism comparable with that of the Greenstones. It can be argued that they must have shared too the later metamorphism which affected the Neranleigh-Fernvale Group, but the additional effects of this on the rocks under consideration would presumably have been slight and certainly are difficult to detect. Some members of the group have also been deformed to varying degrees by one or both of two distinct episodes of purely dynamic character.

(i.) THE BUNYA PHYLLITES (undeformed). These correspond to the Bunya Phyllites as defined and mapped by us (1951) but not to the Bunya Series of Denmead (1928) which was more extensive and lithologically less uniform including rocks of various types which we have assigned to the St. Lucia Polymetamorphics, the Hamilton Cataclasites and undeformed members of the Neranleigh-Fernvale Group respectively.

The undeformed Phyllities are typically developed in the suburb of Indooroopilly especially in the railway cutting and nearby where they occupy the crest of a denuded anticline and dip gently beneath the St. Lucia Polymetamorphics which overlie them both to the north-east and to the south-west. They thus form a window in the Polymetamorphics extending from this, their southern-most point at Witton Creek, in a gradually widening wedge to the north-west. They have been subjected successively to a mild and later even milder regional metamorphism and, locally, to a yet later moderate thermal metamorphism from the Enoggera pluton and its subjacent extensions.

As seen in the field the Bunya Phyllites are fine-grained pelitic metamorphics which are so deeply weathered that it is difficult to obtain fresh unoxidised specimens for study. Fortunately some of the material from the lower levels of the University Training Mine at Indooroopilly is quite unweathered and this has been used as a basis for microscopical examination and for the rock analysis shown below.

The rock is finely phyllitic in character although in places it presents certain more coarsely schistose features and the question arises whether it is a phyllonite due to retrogressive metamorphism of a schistose rock of somewhat higher grade, rather than simply a phyllite due to the positive effect of mild regional metamorphism. Phyllonitization, if it did occur, was so remarkably complete that no sure evidence of it remains.

The Bunya Phyllite consists essentially of parallel alternating wider bands of micaceous and narrower bands of quartzitic character along and across which veins of white quartz have been intruded.

The micaceous bands which make up the bulk of the rock, although dark in colour owing to the presence of graphite, are composed essentially of innumerable small platy crystals of sericite in parallel arrangements. The quartzitic bands are relatively narrow and are made up of an even-grained mosaic of very small quartz crystals between which are dispersed numerous minute crystals of green chlorite, the majority of which are elongated parallel to the length of the bands.

It is clear that these two assemblages represent the original pelitic sediment from which the phyllite was derived and that the rock consists essentially of a muscovite, chlorite, quartz assembly and as such falls naturally into the muscovite-chlorite sub-facies of the green-schist facies. This very moderate metamorphism is in keeping with Mathew's findings for the Rocksberg Greenstones and interbedded phyllites. The white quartz veins, which show some signs of strain, were introduced after the phyllite was produced. They are lighter in colour and coarser in texture than the quartz-chlorite aggregates and contain rare crystals of tourmaline and a plagioclase felspar.

The analysis of a typical example of the Bunya Phyllites collected from the University of Queensland Training Mine at Finney's Hill is appended.

	Per cent.		Per cent.
SiO_2	63·0	TiO_2	0·70
Al_2O_3	14·53	CO_2	0·14
Fe_2O_3	3·81	C	0·12
FeO	4·80	P_2O_5	0·20
MgO	2·28	MnO	0·63
CaO	0·55	PbO	0·32
Na_2O	0·92	S	0·06
K_2O	2·75	H_2O+	4·33
BaO	0·05	H_2O-	0·59
		Total	99·78

(ii.) THE ST. LUCIA POLYMETAMORPHICS. In the recently published Geological Map of the City of Brisbane and in the Explanatory Notes that accompany it (1951) we introduced the term Polymetamorphics to distinguish those members of the Brisbane Metamorphics which showed evidence of a more complicated metamorphic history than their fellows, as indicated by their appearance in the field, in the hand specimen and under the microscope. Within this group we recognised and mapped two distinct facies which we named the St. Lucia and Hamilton Polymetamorphics respectively. In the same publication we expressed the opinion that "Although lithologically different, the Hamilton rocks are thought to be equivalent to those at St. Lucia." A reconsideration of the evidence then available together with the appraisal of the new information since collected leads us now to reject that correlation. We now regard the St. Lucia Polymetamorphics and the Hamilton rocks as distinct stratigraphically as they are lithologically, their only remaining bond being the evidence they both show of severe deformation.

The St. Lucia Polymetamorphics occupy two belts which converge to the south where, at Indooroopilly, they are only a mile apart. The eastern limit of the main development is determined by the Normanby Fault beyond which there occur only a few isolated narrow strips such as those from Turbot Street to Vulture Street and from Ivory Street to the foundations of the Story Bridge. The western limit is similarly marked by the Kenmore fault. How far they extend to the north is unknown, but Dr. Gradwell has collected typical material from the Samford Range.

The resemblances between the St. Lucia Polymetamorphics and the Bunya Phyllites are such that there can be little doubt that both were derived from similar pelitic material, but they go further than that and strongly suggest, if they do not convincingly establish, that the Polymetamorphics were derived by deformation directly from the Phyllites themselves. Detailed examination shows that the minerals are identical in kind and proportion and that the very striking differences in general appearance of the two rocks are due only to the different textural arrangement of these minerals.

Within the St. Lucia Polymetamorphics all the members show clear evidence of mechanical deformation, but very considerable diversity exists in the manner in which it is displayed and in the degree of its development. But although striking contrasts in both qualitative and quantitative effects can be found in the field and under the microscope, gradations between what at first seem to be distinctive lithological types can be found. This should be borne in mind when reading the descriptions of the three types set out below.

(*a*) The Milton Type. This shows the Polymetamorphics in their most complex and intricate development which gives them a superficial resemblance to migmatites and the appearance of great antiquity. Thus Jensen (1910) expressed the opinion that "The Brisbane Schists . . . are so crushed, folded, foliated and faulted that they must be assigned to the Middle Zone. . . ." The same reasons led Wearne (1912) to suggest a Pre-Cambrian age for the "Brisbane Schists." In the field the rocks appear as an intricate, highly involved and dislocated aggregate of alternating bands of micaceous minerals and dark flint-like material, along and across which are very numerous veins of white quartz. It is clear that the original rock is represented by the micaceous bands (which frequently show fine examples of strain-slip cleavage), and the black quartzitic bands, many of which have been pinched to form strings of lenses, interrupted as semi-isolated lunules, twisted into intricate knots or broken into detached individual lenses. The white quartz veins, which have clearly invaded the rock subsequent to its original deformation, have been involved in a further deformation which has folded and strained them strongly as well as intensifying and complicating the earlier structures of the micaceous and quartzitic bands.

The dip, if such it can be called, of these highly contorted beds is usually very steep, and small overfolds and overthrusts are common. Most of the outcrops are so deeply weathered that it is difficult to collect specimens suitable for microscopic examination, but fortunately fresh material was made available by the excavations for the piers of the Grey Street Bridge. In his original description of this material, Richards (1931) wrote:—"When fresh [they] are a dark blue or grey colour and exhibit a plication usually well-developed owing to the fine-grained character . . . . . . Puckering on a minute but intense scale is a frequent characteristic . . . . . . A tough knotted character is induced in the rock by this fine puckering . . . " Richards also stated that "The quartz veins in these schists are of two different kinds. One kind is a dark bluish grey in colour and appears to have resulted from a metasomatic replacement of the schistose material. Those veins are the most abundant and are veins of quartzite rather than quartz. The quartz veins proper are generally larger, are white and much less regular in their development [i.e. distribution]." With regard to the development of the more interesting characteristics of this very unusual rock Richards made the following comments: "The microscopic characters of the rocks show clearly that much of the schistose or phyllitic material has been replaced by silica. The original bedded structure and the later induced schistose structure are both sometimes preserved in the [dark] quartz veins formed by the metasomatic replacement of the schistose material. Throughout the quartz there is a fine dust of the graphitic and other small mineral particles which were not replaced."

After re-examining the material on which the above statements were based and preparing additional microslides we are in a position to confirm Richards' descriptions in most essentials, but find ourselves in disagreement with some of the explanations provided for the structures described.

Our principal point of disagreement concerns the origin of what for the purpose of simplicity we shall refer to as the "black quartz". Under the microscope this appears at first glance to be, as Richards suggested, a quartzitic aggregate darkened by opaque graphitic smudges, but examination under high power shows that the smudges are produced by myriads of minute greenish transparent crystals, the larger of which are recognisably chloritic. This quartz-chlorite aggregate is not, in our opinion, the result of metasomatic replacement, but of microbrecciation and recrystallization brought about by the play of severely deformative mechanical forces.

The minute green crystals are not uniformly distributed in the aggregate but are arranged in streaks or smears roughly parallel to the margins of the veins and separated by relatively clear lanes. Such an arrangement is probably due to the crushing and orientation of quartz-chlorite aggregates such as those already described as forming bands in the undeformed Bunya Phyllites.

We agree with Richards that the white, less finely crystalline quartz veins, although they may represent more than one generation, are all of them later than the black quartz aggregates which they often intersect. But some of these show clearly that they too, although they followed the deformative effects outlined above, have been subjected to severe stresses. Evidence of this is seen in the shape of many actual fractures (in some cases to produce a quartzitic breccia) and numerous incipient fractures indicated by very pronounced strain lamellae and undulose extinction. Many of these veins, which we will refer to as the "white quartz", are highly contorted. This may be due in part to their having followed contortions in the host rock produced by the earlier deformation, but as they invariably show signs of strain, part of the contortion must be due to a later deformation. In addition the larger white quartz veins may be seen in many places in the field to be overturned with well developed patterns of tension cracks on the overfold.

This later deformation which has affected the white quartz veins has also produced recognisable secondary effects in the main body of the rock. This is shown especially by the development within the micaceous bands of well-developed strain-slip cleavage (*Umfaltungs Klivag*), and by the production of secondary streaks in the black-quartz bands which are related to the primary streaks like the woof to the web in a woven material. Further, the direction of both the false cleavage and the secondary streaks appears to be related to the overfolds in the white quartz veins. Although under the microscope, the differential effects due to each of the two thrusts can be clearly distinguished, macroscopically, it is very difficult to distinguish the earlier effects from those superimposed by the later deformation.

In all, the evidence points to Polymetamorphics of the Milton type as having suffered, in addition to regional metamorphism which produced schistosity almost parallel to the bedding, two distinct episodes of deformation. Also, where these rocks came within the thermal reach of the Enoggera pluton, a contact metamorphism was superimposed on the regional and kinetic effects to give a strongly contorted but non-fissile hornfels.

(*b*) The Ironside Type. This differs from the type described above in its comparative simplicity and regularity of structure. Whereas at Milton the structure is so confused as to be almost chaotic, at Ironside the rocks appear to have a comparatively gentle dip and a pronounced parallelism that gives the impression of a regularly bedded deposit, although closer examination reveals that they are minutely and intricately involved. The veins of white quartz in particular, strengthen the illusion. It would seem that here we have all the features of the early deformation as indicated by the irregular and distorted character of the black quartz, only slightly complicated by the later deformation as indicated by the regularity of the white quartz. That the differences between the Ironside and Milton types are quantitative and spatial, rather than qualitative and temporal, is seen in the field where the gently dipping and compartively simple beds of Ironside type are found to grade imperceptibly into the steep and highly complex masses of the Milton Type (and by the strong evidence of strain within the apparently undisturbed quartz veins).

(*c*) The Taringa Type. In the western part of the suburb of Taringa there occur Phyllites of the Indooroopilly type which, while they lack the features indicative of the earlier deformation, show evidence of strain-slip cleavage and possess the numerous closely folded and strained veins of white quartz characteristic of the second deformation. Evidently the rocks in this area occupied a position sheltered from the earlier deformative forces but exposed to those of the later more wide-spread deformation.

(D) The Neranleigh-Fernvale Group.

This Group we now regard as including not only the normal very mildly metamorphosed sediments as hitherto, but also the Hamilton Cataclasites previously mapped by Denmead as part of his Bunya Series.

(i.) THE NERANLEIGH-FERNVALE GROUP (Undeformed). The lower members of this group outcrop over wide areas of Greater Brisbane, and although relatively "undeformed", show in many places strain phenomena mildly developed. As mapped by us, they occupy a much greater area than that indicated in Denmead's (1928) map. In particular, a large area to the east of the City and to the north of the Brisbane River assigned by Denmead to his Bunya Series consists we think, of the northerly prolongation of his Neranleigh Series which his map shows as confined to the south of the river. In support of this contention, we submit that much of the material to the north of the river, as at Wilston, Newmarket and Alderley, is on the same regional strike as, and lithologically identical or very similar to, Denmead's Neranleigh Series. This applies particularly to the banded slates and to the much-contorted, thin-bedded quartzites, although admittedly the greywackes are less common to the north of the river.

The area thus extended now includes within the Neranleigh-Fernvale territory the locality from which the specimen was obtained for the chemical analysis of Denmead's (1928) Bunya Series. It is significant we think that this analysis is quite similar to that published by Denmead of his typical Neranleigh greywacke, especially in its high soda content which is more than twice that to be expected in a phyllite. It is equally significant that Denmead's analysis is dissimilar from that of the Indooroopilly rock selected by us as typical of the Bunya Phyllites particularly in the low soda content of the latter.

The rocks of the Neranleigh-Fernvale Group form a heterogeneous assemblage that is in striking contrast to the uniformity of the Bunya Phyllites. This is especially true of the Group as developed to the west of Kenmore. Composed essentially of an irregular alternation of pelitic types like banded shales and psammitic types like massive greywackes, they also include highly siliceous rocks like cherts and jaspers, while impure limestones and at least one phosphatic horizon are also present.

They differ too in that the total regional metamorphism they have experienced is notably milder than that to which the phyllites were subjected. Similar pelitic sediments have been changed to slates in one case and to phyllites in the other.

It is difficult to select a "type" in such a varied assemblage as is found in the Neranleigh-Fernvale Group, but Denmead has pointed out that greywackes are the most conspicuous rocks in the lower part of the Group.

We append here three analyses. No. 1 is that given by Denmead of a typical greywacke from his Neranleigh Series as developed at Bethania Junction 18 miles S.E. of Brisbane. No. 2 is that of the analysis from the city of Brisbane, attributed by Denmead (wrongly, we think) to the Bunya Phyllites, and No. 3, kindly supplied by Dr. R. Gradwell, is that from the northerly development of the Neranleigh at Mt. Nebo, 13 miles N.E. of Brisbane.

	1.	2.	3.
	Per cent.	Per cent.	Per cent.
SiO_2	68·54	61·62	66·06
Al_2O_3	15·49	21·20	15·34
Fe_2O_3	0·88	1·51	1·01
FeO	3·17	1·93	4·58
MgO	1·23	1·77	2·85
CaO	2·24	1·59	2·38
Na_2O	3·04	3·39	3·21
K_2O	3·50	3·07	4·00
H_2O+	0·75	3·29	0·36
H_2O-	0·15	0·03	0·16
TiO_2	0·59	0·82	0·62
P_2O_5	0·16	0·17	0·09
MnO	0·08	0·07	0·04
Total	99·82	100·56	100·70

The localities from which the specimens were collected on which these analyses are based all fall within the area which we regard as occupied by the Neranleigh-Fernvale Group. It is noteworthy that not only are the analyses similar, but the high soda content of all is unusual for rocks of sedimentary origin. Thus the evidence of the analyses supports the field evidence that the rocks from which they were made belong to one and the same series.

(ii.) THE HAMILTON CATACLASITES are closely associated geographically with the Neranleigh-Fernvale distribution as interpreted by us, and show evidence of having been produced by the deformation of these or similar rocks. (Indeed the "undeformed" Neranleigh shows signs of strain over a very large area.) They are roughly equivalent to Denmead's (1928) "Hamilton Schists." Of the Neranleigh-Hamilton relationship Denmead (p. 98) wrote: "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." Denmead concludes that "The only reasonable explanation of these facts . . . . . is an over-thrust fault."

The Cataclasites of Hamilton differ rather markedly from the Polymetamorphics of St. Lucia both qualitatively in their typically psammitic character and quantitatively in the scale of the structures exhibited, although of course these differences may well be related. The grossness of structure is determined, at least in part, by the coarseness of grain of the rocks involved. That the phenomena observed at Hamilton have been brought about by forces similar in kind to those which produced the St. Lucia rocks is demonstrated where an occasional pelitic stratum is interbedded with the dominating psammites. At such places, as for instance in Hamilton Road, minor plications and minute convolutions are to be seen. But relatively large scale overfolds and overthrusts are usually the most conspicuous characteristics of the Hamilton rocks as seen in the field. They are so numerous as to form in places an almost chaotic jumble. Nevertheless, a fundamental uniformity of pattern does exist. Although, observed from a distance, the rocks appear to have a regular strike and a dip which can be readily measured by sighting on them with a clinometer, on closer inspection the "dip" proves to be the expression of an imbricate structure, a kind of gigantic cleavage, consisting of parallel shear planes, the bedding proper as seen between these planes being very irregular and involved. One interesting feature is that the cylindrical rolls in the axial portions of the overfolds resemble superficially the trunks of large fossil trees.

In many places, not only the rocks themselves but the white quartz veins which penetrate them show obvious signs of having been sheared and shattered.

Associated with this strongly overfolded and overthrust material there occur on many horizons, and particularly towards the base of the disturbed material, sandy strata that have been crushed into extraordinary fine-grained, weakly coherent cataclasites made up entirely of rock flour. These are well shown immediately behind Dalgety's Wharf at New Farm and in Adelaide Street in the city.

The Hamilton Cataclasites resemble the St. Lucia Polymetamorphics in that they clearly show the effects of mechanical deformation, but differ from them in several important respects. Briefly these are: The Hamilton rocks have experienced only one regional metamorphism, and that a very mild one; the "black quartz" is conspicuous by its absence; the only deformation exhibited involves the white quartz veins; the structures produced are on a larger scale; and microbrecciation is more pronounced.

Under the microscope the Hamilton rocks examined are typically psammitic and made up essentially of detrital quartz and felspar. Veins of white quartz are numerous. Evidence of microbrecciation of rock proper is abundantly clear and is accompanied by equally severe strain effects in the white quartz veins. No "black quartz" is present.

Where occasional more pelitic strata are found they show signs of a very mild regional metamorphism imposed before the deformation which brought about strain-slip cleavage in the sericitic bands and granulation of the remainder of the rocks, including the white quartz veins.

As a result of these differences, the Hamilton rocks cannot be matched against any of the three types of St. Lucia Polymetamorphics. The evidence of the microscope shows that Hamilton has shared only the latter part of the varied tectonic history of St. Lucia.

III. STRUCTURAL RELATIONSHIPS.

(A) The Indooroopilly Anticline.

This feature which was first named and described by Denmead (1928) is, as he rightly pointed out, the dominant structure of the area. As far as research has as yet proceeded, it appears originally to have been no more than a simple anticline. But it is most unusual for such a very large structure to be of such a simple pattern and future work may prove it to have been quite complex. David (1932) seems to have had this possibility in mind when he introduced the term "Brisbane Geanticline" for the same structure.

The anticline is notably asymmetrical, the dips on the north-eastern limb are on the whole less steep than those on the south-western flank. Except for a few unimportant local reversals, the north-easterly dips are consistent in direction over a minimum distance of seven miles, from the axis to the point where the Brisbane Metamorphics disappear beneath a cover of younger rocks. On the other hand the amount of dip is by no means consistent, alternating as it does between very steep and moderate. But the steeper dips are not, in our opinion, original but have been superimposed subsequently on the anticline by steep reverse faults associated with thrusting movements. (See Section IIID, The Hamilton Thrust).

The south-western flank of the anticline presents a very different picture. Not only are the dips commonly very steep but they alternate in direction. They show no signs of having been exaggerated by the later thrusts. Such asymmetry suggests that the anticline was elevated by pressure from the north-east. The axis has been traced by Denmead (1928) from Indooroopilly in a north-westerly direction to a point near Woodford, forty miles away. Taylor Range marks the position of the axis near its south-eastern limit which is formed by the Brisbane River near Indooroopilly, where the horizontal strata forming the crest of the fold may be seen in cliffs on the riverbank. The structure pitches gently to the south-east beneath a cover of Mesozoic and later rocks. It has a breadth, as measured from Pullen Creek to Hamilton, of approximately twelve miles.

Earlier interpretations of the history of the anticline suggested that strata of a total thickness of 50,000 feet were involved, and that the crest at its maximum may have reached a height of 30,000 feet. Indeed David (1932) described the structure as "the core of a huge geanticline, originally perhaps at least as high as the Himalayas."

In our view the Indooroopilly Anticline, although an imposing structure, never reached the heights that David suggested, for we hold that it was elevated in at least two stages, once before and once after the deposition of the Neranleigh-Fernvale Group, and that a considerable erosion interval occurred between the orogenies. Our cross-section (Figure 2) suggests a height of the order of 10,000 feet.

(B) The Unconformity Between the Bunya Phyllites and the Neranleigh-Fernvale Group.

As defined and mapped by us the Bunya Phyllites constitute a homogeneous, almost purely pelitic facies which probably accumulated slowly under deep water, whereas the Neranleigh-Fernvale Group is a heterogeneous one, in which psammitic types are well represented, deposited quickly under rapidly changing conditions, in which the water was commonly shallow. In short, although both series are geosynclinal, the Bunya Phyllites represent accumulation under static conditions, whereas the Neranleigh-Fernvale Group represents accumulation under dynamic conditions.

Another important difference is that the older series clearly shows the effects of regional metamorphism, whereas the equally sensitive pelitic strata in the younger group show only traces of a mild metamorphism and, further, they sometimes contain fragmentary fossil plants.

If we assume that the St. Lucia Polymetamorphics are coeval with the Bunya Phyllites and the Neranleigh-Fernvale Group with the Hamilton Cataclasites, we have further indirect evidence of an important time break, for the former show clear evidence of two epochs of deformation (separated by the invasion of white quartz), while the latter show only the effects of the second deformation.

Direct structural evidence of such an unconformity would however be difficult to find, for we hold that the later orogeny, which affected all the Brisbane Metamorphics, was strictly supplementary to the earlier orogeny which had already folded the Bunya Phyllites, and that consequently, the effect of the second orogeny was to emphasize the regional strike and the principal structures produced by the first. One could not expect therefore to find either unconformity of strike or reversal of dip as between the two series. Theoretically, the dips of the Phyllites might be expected to have higher values than those of the Neranleigh-Fernvale Group, but such differences would be difficult to determine owing to (*a*) the absence of vertical sections showing the junction of the two series, (*b*) the fact that the dips of both series frequently change in value rather abruptly, and (*c*) the difficulty in some cases of recognising the original bedding in the strongly foliated Phyllites.

Nevertheless, numerous observations indicate that, on the whole, the strike of the Bunya Phyllites is more nearly meridional than that of the later group, and the dip is somewhat steeper.

(C) The St. Lucia Thrust.

In the earlier work already referred to (1951), we advanced the opinion that a single great thrust, "The Brisbane Thrust," was responsible for the deformation of both the St. Lucia Polymetamorphics and the Hamilton Cataclasites, but we now hold that the former series shows evidence in the hand specimen and under the microscope of having undergone an earlier deformation before that which it shared with the Hamilton Cataclasites. We hold further that this earlier deformation was brought about by an earlier thrust, here called the St. Lucia Thrust, which, as it anticipated many of the features of the Hamilton Thrust, is less obvious in the field. The Hamilton Thrust added to, but at the same time overshadowed and largely obscured, the effects of the earlier thrust.

In the early part of our investigations the much-metamorphosed rocks that we have since called the St. Lucia Polymetamorphics were assumed from their ancient appearance to form the basement upon which the less metamorphosed Bunya Phyllites rest. But, to our surprise, field investigations have shown that where the Polymetamorphics and the Phyllites are in conjunction the former always occupy the position expected of the younger series.

The consistency with which these apparently older rocks occupy the higher position can be explained only in terms of overfolding or overthrusting. The former possibility was examined first, but no scheme of overfolding either simple or complex appeared adequate to explain even the larger features of distribution. By contrast, the latter alternative proved helpful from the start, and in the end, the hypothesis of overthrusting which was originally introduced to explain the distribution of the Polymetamorphics in the field proved adequate to explain too the intense deformation of these rocks as expressed by their lithology and texture.

Search for this thrust-plane did not disclose any obvious structure of that nature, and it may well be that, under the particular set of conditions prevailing, the thrust-plane (so-called) may not have been either strictly planar or confined to one horizon. Added to this, we believe that since its formation it has been successively folded into an anticline, disturbed by a later thrust, further folded, partitioned and displaced by normal faulting, covered in part by sediments and partially removed by erosion. It is not surprising that the "plane" as such is not readily recognisable.

Only rarely, as at Hart's Road, Indooroopilly and near the Toowong Cemetery (where the effects peculiar to the earlier thrust are well displayed) are the two series which are separated by the St. Lucia overthrust seen in close juxtaposition. At other places, where the superposition of the Polymetamorphics has been established by the field evidence, the actual junctions are obscure. However, if the actual "sole" is not in evidence the lowest parts of the St. Lucia Polymetamorphics are especially rich in minor overthrusts, while in the uppermost part of the over-ridden Phyllities, numerous dragfolds occur and these, with the added evidence of numerous intense slickensides, point to the proximity of the main thrust.

While to the north-east of the Indooroopilly Anticline the minor overfolds and overthrusts are directed up the dip, although at somewhat steeper angles, on the south-western limb the overfolds are diverted down the dip, but at gentler angles. From this it is clear that the thrust-plane and overlying sheet of Polymetamorphics were involved in the movement that finally produced the Indooroopilly Anticline.

Although there are a few minor incidental exceptions, the evidence of numerous and widely scattered overfolds points convincingly to the overthrusting having been produced by pressure from a north-easterly direction. How far the sheet has travelled and to what extent it is allochthonous we have been unable to determine as its north-eastern limit is a faulted one, beyond which its possible extension is hidden beneath younger rocks. But the close mineralogical resemblance of the material of the sheet to that of the underlying Bunya Phyllites suggests that it may well be autochthonous or that it has travelled only a short distance. The discontinuous remnants of the sheet measure five miles across the strike from the Grey Street Bridge to Chappel Hill, while they extend ten miles along the strike from Fig Tree Pocket to the northern boundary of the City of Brisbane. Beyond this, their northern limit is as yet unknown, although Dr. R. Gradwell has collected typical St. Lucia material from the top of the Samford Range. Equally little is known of the original thickness of the sheet, but measurements between Indooroopilly and Kenmore suggest a minimum thickness of 1,300 feet.

(D) The Hamilton Thrust.

While the proof of the existence of the St. Lucia Thrust rests largely on the study of thin sections, the Hamilton Thrust is securely based upon field observations.

The direction, intensity and general microscopic effects of the Hamilton Thrust are broadly comparable with those assigned to the St. Lucia Thrust. The interval between the two thrusts was a very considerable one, during which the Neranleigh-Fernvale Group had been laid down and the whole area invaded by innumerable veins of white quartz. The structures produced varied in scale in accordance with the character of the rocks affected. Thus at Hamilton, where psammitic types are the rule, relatively large-scale structures are to be seen, whereas in areas where pelitic types are dominant, as at Milton, the structures are much smaller and are closely comparable to those due to the earlier St. Lucia thrust.

However, some of the minor effects, such as the straining of the white quartz and the development of incipient strain-slip cleavage in the micaceous bands, are wide-spread and extend well beyond the margins of the area which we have mapped as occupied by the Hamilton Cataclasites.

The geographical distribution of the Cataclasites suggests that the second thrust came from much the same direction as the first but at a more gentle angle* with the result that at Hamilton the second thrust is well above the first, while at Taringa they are almost coincident.

In spite of the severity of the deformative effects shown by them, the Hamilton Cataclasites are lithologically so closely similar to typical members of the Neranleigh-Fernvale Group that they too must be regarded as virtually autochthonous.

Associated with the main Hamilton Thrust there appears to have been a series of reverse faults, some of them quite steep. To the east, as at Hamilton, Booroodabin and New Farm, these affected only Neranleigh-Fernvale sediments, but in the city, as near the Story Bridge, at All Hallows Convent and at the Dental College, the uppermost parts of the St. Lucia Polymetamorphics were also scooped up, while still further west at Toowong, the St. Lucia rocks only were involved in these steep upthrusts. The relative degrees to which various areas were affected by these minor thrusts are shown almost diagrammatically by varying degrees of irregularity of the white quartz veins. Where the rocks, whatever they may be, are least affected and dip most gently the white quartz veins present an undisturbed bedded appearance, but as one proceeds down the dip towards the reverse faults and as the dips steepen progressively, quartz veins become gradually less regular until they become folded and twisted into a confused tangle.

(E) The Buranda Fault.

There is a marked lack of harmony both stratigraphical and structural between those members of the Brisbane Metamorphics developed in the north-western suburbs of the city and those found to the south-east. This is especially noticeable owing to the fact that the regional strike is directed approximately from one to the other of these areas.

Clearly, some kind of discontinuity exists. Denmead (1928) was the first to recognise this discordance. He placed the dividing line roughly in the position of the Brisbane River and explained it as due to a zone of dip-faults with downthrow to the south-east, which affected not only the Brisbane Metamorphics but the Mesozoic rocks which in places overlie them.

In contrast to Denmead's interpretation, we place the discontinuity somewhat further to the south-east at what we have termed the Buranda Fault, which we now hold to be a "tear," "wrench," or "transcurrent" fault with sinistral displacement, which occurred in pre-Mesozoic times as the final effort of the compressive movement that brought about the Hamilton Thrust.

To the south-east of the fault the only representatives of the Brisbane Metamorphics to be found are members of the Neranleigh-Fernvale Group, whereas to the north-west there are developed in addition to these the Bunya Phyllites, the St. Lucia Polymetamorphics and the Hamilton Cataclasites. It is, we think, particularly significant that the southerly extension of the last of these should be so abruptly terminated by the Buranda Fault.

The fault itself cannot be traced continuously owing to its having been covered in places by Mesozoic and Tertiary sediments and by recent alluvium. Nevertheless it is well developed at several points

* Alternatively the St. Lucia Thrust may have been tilted somewhat before the Hamilton Thrust was produced.

which are virtually colinear, and where its presence is indicated by fault breccias, slickensided surfaces and disturbance of strike due to horizontal drag. In particular, in the neighbourhood of Corinda, intense disturbance, brecciation and slickensiding can be seen in the abandoned Council quarry, while nearby, at the Carrington Rocks, banded quartzites of the Neranleigh-Fernvale Group have been dragged from their normal N.50°W. strike to a N.100°W. direction. Again, at the other extremity of the fault as mapped, there is a well-developed zone of fault-breccia at Cannon Hill, where Muir Street intersects Erica Street, and a strong swing from the regional strike towards parallelism with the line of fault. On each side of the fault as here developed the local change in strike suggests movement in the sinistral sense.

In the earlier work (Bryan and Jones, 1951) we have depicted the Buranda Fault as one of a series of normal faults due to tensional reaction following the completion of the thrusting movements, but we now prefer to remove it from that series and to interpret it as a tear fault with sinistral displacement for the following reasons:—

1. The local evidence of faulting wherever found along the Buranda line is at least as compatible with a tear fault as with a normal fault.
2. Such a fault would explain all that a normal fault explains, and at least as convincingly.
3. Additionally, by assuming a horizontal displacement of appropriate dimensions, it would bring into geological and geographical harmony features that are now discordant. For example, the several prominent quartzite hills of the Mt. Gravatt area could be matched against those of the Brookfield area, while the folds of Coorparoo which do not continue across the Buranda Fault would find their counterparts near Moggill.
4. The assumption of such a forward movement across the strike of the north-western portion would place the fault neatly into the structural picture as one of the several related results of the Hamilton Thrust.
5. It would remove from the list of normal faults the only exception to the generalization that these form a parallel series in the general direction of strike.

F. The Normal Faults.

These tensional faults are very numerous especially in the approximate direction of the regional strike. They are readily recognised where the throw is small and the amount of displacement can be observed, as in deep cuttings. At the other end of the scale too, they are readily deduced where the throw is sufficiently great to bring lithologically different series into juxtaposition. But there are in addition very numerous faults of moderate throw where neither of the above conditions apply and where the only visible evidence of faulting is that of disturbance about a steeply dipping plane. In such cases the direction of throw must remain in doubt, and we cannot know whether the effects of these faults are cumulative or whether they tend to cancel out.

The normal faults are later than the thrusts, as may be seen in the road cuttings on St. Lucia Road, where numerous small tensional faults displace the minor thrust-planes.

The larger of the normal faults determine, in part at least, the present limits of the deformed beds. Thus the Kenmore Fault, a near-strike fault with a large downthrow to the west, forms the western boundary of the St. Lucia Polymetaporphics. It has been recognised at intervals from the Mt. Nebo Road to Fig Tree Pocket.

The eastern boundary of the Hamilton Cataclasites may be provided by a large fault for it is the nature of a steep scarp* against which the much younger Ipswich Coal Measures lie. This may well be a fault-line scarp, the fault itself having occurred in pre-Mesozoic times, concurrent with that just considered.

The most conspicuous and probably the most important of the other normal faults is the Normanby Fault which approximately follows the regional north-westerly strike for at least twelve miles from a point in Bracken street, Moorooka, where it is strongly developed and where an arresting fault breccia may be seen, to the city boundary near Bunyaville. It may be examined, too, at several intermediate points, as for example, under the northern end of the Grey Street Bridge, near the intersection of Windsor Road and Victoria Street, and at the City Council Quarry on Samford Road near Alderley. The amount of the throw which has brought the Neranleigh-Fernvale Group down against the St. Lucia Polymetamorphics is unknown, but probably it is of the order of hundreds of feet as shown in the accompanying section.

Evidence of other major faults of a tensional character may be seen near Windsor railway station where a course fault breccia is developed. This we have named the Windsor Fault. Although hidden beneath a considerable width of Mesozoic strata, an extension in a direction parallel to that of the other normal faults would carry it to the well-developed fault-breccias in East Brisbane near Norman Crescent. Another strongly developed fault of this series may be seen in the abandoned Morningside Quarry near Richmond Road. Here, relatively undisturbed members of the Neranleigh-Fernvale Group lie against typical Hamilton Cataclasites, the faulted junction running in a north-westerly direction. The fault plane with its slickensides and breccias is clearly seen to form the south-western edge of the deepened quarry.

Other similar and parallel faults may be deduced from the distribution pattern of the Brisbane Metamorphics. In some cases, as at the mouth of Breakfast Creek the faults so deduced are supported by obvious signs of disturbance. Yet further members of this group may have effected considerable total displacement although none has had a sufficiently large throw to modify the distribution of the Metamorphics as shown on a small scale map.

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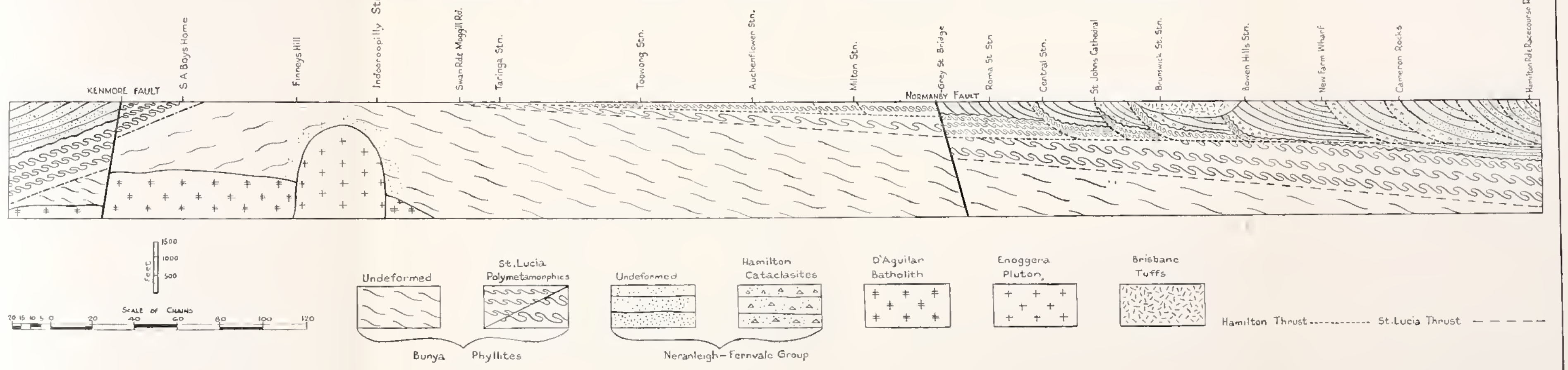
* The steepness of the scarp is demonstrated by the fact that in a bore on the Ascot racecourse, only half a mile from the boundary, the Metamorphics were not encountered until 1,680 feet.

Diagrammatic Section from Kenmore to Hamilton



IV. SIGNIFICANT IGNEOUS EVENTS.

This section does not aim at giving a complete account of all the igneous episodes that occurred during the prolonged history of the Brisbane Metamorphics. Instead attention is directed to those events which, in our opinion, are closely relevant to the structural history of the Brisbane Metamorphics.

A. The D'Aguilar Batholith.

This is the name, already in use by local geologists, for the supposedly continuous batholithic mass which reinforces the D'Aguilar Block to the north of Brisbane and appears at the surface as a number of separate outcrops. The larger of those which occur within or infringe upon the boundaries of the city of Brisbane are at Mt. Crosby, Camp Mountain and Enoggera. The last of these is the most interesting and important from the point of view of this discussion and will be dealt with later in a separate section under the caption "The Enoggera Pluton".

The batholith is, we hold, composite in character, for the constituent parts differ from each other, not only petrologically, but in age, in mode of emplacement and in metamorphic effects.

The earliest evidence of the existence of the batholith appears to be provided by the white quartz veins, although these have not in fact been traced to their source. These veins are extremely numerous. In size, they vary from microscopic to veins several inches in width. They characteristically follow the bedding even when it is highly deformed. They occur over a very large area, and are particularly plentiful in the Bunya Phyllites and the St. Lucia Polymetamorphics. They are common too in the Hamilton Cataclasites and the associated Neranleigh-Fernvale of the eastern suburbs, but they are relatively rare in those members of the Group developed west of the Kenmore fault. They are not found in any post-Palaozoic rocks.

In keeping with their uniformly white colour they are remarkably pure quartz veins, but triclinic felspars are not uncommon in pegmatitic intergrowths, thus clearly indicating an igneous origin for these veins.

Of similar significance is the presence of brown tourmaline. The crystals are very minute and are very rare, but they are all very similar in colour and crystalline form and are scattered over a very large area, reaching from St. Lucia to Galloway's Hill in the east to the Samford Range in the north. At one point near the top of the Samford Range, small crystals of andalusite were found.

The white quartz veins are intrusive in character. They are later than the St. Lucia Thrust, for they frequently intersect the microstructures produced by that thrust. In particular, they are definitely later than the black quartz veins which were originally bedded and which they often cross at right angles.

On the other hand, the white quartz veins are earlier than the Hamilton Thrust which has caused them, in places, to be twisted into ptygmatic forms, while the individual crystals have been strained and even brecciated to give typical mortar structure. Many of the tourmaline crystals and those of andalusite have also been fractured, and the broken fragments displaced.

Since the white quartz veins must have been derived from some adjacent igneous intrusion, their relationship to the Enoggera pluton was investigated with particular care, as it would seem to have been the most obvious source. But the results of this examination were somewhat surprising in that they not only failed to disclose any connection, but clearly indicated that the quartz veins were earlier than the pluton. The evidence for this conclusion is that:—

1. In the field where sharp contacts could be found, as in Ithaca Creek and on the Cedar Creek road, large white quartz veins were sharply truncated and turned up slightly by the upward movement of the pluton.

2. Xenoliths of Bunya Phyllites were collected containing smaller quartz veins and these also are truncated by the surrounding granite.

3. Under the microscope still smaller but essentially similar examples may be seen.

4. It may be significant too that the tourmaline found in the marginal parts of the granite does not occur as isolated brown crystals like those of the quartz veins, but as radiating aggregates of the black variety, schorl.

Clearly these white quartz veins were emplaced before the intrusion of the Enoggera pluton and we are led to suppose they came from a subjacent igneous mass (perhaps the original "D'Aguilar Batholith") from which the pluton itself may well have been derived at a later date.

(B) The Intrusive Rhyolites.

In a paper on "The Enoggera Granite and the Allied Intrusives" one of us (Bryan 1914-1922) pointed out that the field distribution of the intrusive rhyolites of the Indooroopilly area suggested that they were earlier than those other intrusions of porphyrite, which are clearly related to the Enoggera mass. Nevertheless, as the title of the paper indicated, he regarded the rhyolitic intrusions also as probably allied to the "granite".

Observations made during the present enquiry show that these acid intrusions occur over a much wider area than had been suspected, for typical representatives have been found at Upper Brookfield, four miles south-west of the Enoggera mass and at Bulimba, six miles away to the east. This wider distribution seems to admit of an independant origin of the intrusive rhyolites, and this is supported to some extent by their lithological uniformity over such a large area, by the fact that mineralogically they are generally dissimilar from, and in particular, are less calcic in character than either the granodiorite or the adamellite, and by their far more intense silicification. We suggest therefore that these rocks were intruded before the Enoggera pluton. Support, although of an indirect character, is given to this conclusion by the following evidence:—(1) At Upper Brookfield, a typical intrusive rhyolite appears to be genetically related to rhyolitic flows of the Brookfield Volcanics almost immediately above it; (2) other rhyolites of this series have suffered contact metamorphism from the intrusion of the Mt. Crosby granodiorite*; (3) the Mt. Crosby granodiorite is probably to be correlated with the grey phase of the Enoggera pluton.

* This interesting relationship was brought to our notice by Dr. R. Gradwell and Mr. J. T. Woods.

A lower limit is given to the age of the rhyolitic intrusions by the fact that at Chappel Hill they break across white quartz veins which had been deformed by the Hamilton Thrust, prior to the intrusion.

(C) The Enoggera Pluton.

This has been described in considerable detail by one of us (Bryan 1914, 1922) and reference will be made here only to its structural aspects. With regard to the relationship of the Enoggera mass to the "schists" which it intrudes, Bryan (1914) stated that "the evidence in general supports the Laccolitic method of intrusion" since "The schists near the contact strike parallel to and dip away from the granite. Here, obviously, great mechanical energy must have been called into play, either in the preparation by folding movements of a cavity or plane of weakness in the schists into which the magma found its way (forming the "phacolite" of Harker) or—and this seems more probable, since the long axis of the intrusion is not sympathetic with the strike of the schists—in the actual lifting up of the schist cover by the invading magma itself to form a typical laccolite".

Denmead (1928) came to a different conclusion, namely that "granites have penetrated and now form cores in the great anticline whose axis passed through Indooroopilly and Dayboro".

After re-examining the margins of the Enoggera mass we are satisfied that in places, as to the north-west of the pluton, the local strike is almost at right angles to the regional strike and is parallel to and obviously produced by the intrusion itself. We conclude that the intrusion played a more active part than that of a phacolite. It did more than conform to an already established structure. If it was not solely responsible for the structure, as we see it today, it at least profoundly modified the earlier structure.

In a number of places, knife-edge contacts of the granite and the metamorphics can be seen, and although aplitic dykes are common, there are virtually no pegmatitic apophyses to be seen. Indeed, the intrusion shows all the phenomena to be expected of subsequent or cross-cutting granites, and none of those usually associated with granitic intrusions of the synchronous type. This conclusion is reinforced by the facts that although the adjacent country rocks are definitely hornfelsed, the contact phenomena are not very intense and are restricted to a fairly narrow band. The most conspicuous mineral within the contact zone is epidote, although schorl is strongly developed at one point. The quartz veins within and near the hornfels zone differ from the "white quartz" which they intersect in showing little or no signs of deformation and in the occurrence of epidote within them.

The Enoggera Pluton which may represent a late-formed cupola arising out of the composite D'Aguilar Batholith is composite, being made up in the main of a granitic rock, "the Pink Phase", which encloses a considerable mass of granodiorite, "the Grey Phase". Xenoliths of the latter are very common in the former and are evidently cognate, and appear to have been carried bodily from some subjacent source. Chemically, as the following analyses clearly indicate, the Grey Phase, although very different from the Pink Phase which followed it, is almost identical with the main mass of the batholith as represented by the quartz-diorite at Camp Mountain.

ROCK ANALYSES.

—	Enoggera Pluton. Main Mass ("Pink Phase").	Enoggera Pluton. Xenoliths ("Grey Phase").	D'Aguilar Batholith as developed at Camp Mountain.
	Per cent.	Per cent.	Per cent.
SiO_2	73·52	61·10	61·54
Al_2O_3	11·05	19·24	19·03
Fe_2O_3	Nil	4·66	Nil
FeO	3·15	..	5·04
MgO	1·03	2·56	2·97
CaO	1·70	5·25	4·90
Na_2O	4·08	3·82	2·84
K_2O	3·99	1·68	2·76
H_2O+	0·44	1·31	0·35
H_2O-	0·16	0·64	0·10
CO_2	..	..	..
TiO_2	0·20	..	0·72
P_2O_5	0·15	..	0·08
Total	99·48	100·34	100·33

(D) The Brisbane Tuffs.

These rhyolitic tuffs and ignimbrites appear to mark the end of an igneous cycle. They succeed a few feet of lacustrine sediments of the Ipswich Coal Measures which rest with a violent unconformity upon the Brisbane Metamorphics. They contain no quartz veins and have not been affected by either thermal or dynamic metamorphism of any sort. They are later than the Hamilton overthrust and later too than the numerous normal faults which followed that thrust.

TABLE OF IGNEOUS EVENTS ASSOCIATED WITH THE D'AGUILAR BATHOLITH.

Mt. Crosby.	Upper Brookfield.	Indooroopilly.	Enoggera.	Camp Mt.	City.
Tuffs					Tuffs
			Adamellite (Pink Phase)		
Quartz Diorite	Porphyrite Dykes	Porphyrite Dykes	Granodiorite (Grey Phase)	Quartz Diorite	
	Rhyolitic Volcanics and Dykes	Rhyolitic Dykes			
		White Quartz Veins			White Quartz Veins

V. INTEGRATION OF STRATIGRAPHIC, TECTONIC, IGNEOUS AND METAMORPHIC EVENTS.

In this contribution to the geology of Brisbane we have attempted to determine the succession of events in a restricted area by the examination of purely internal evidence. As a result of the limitations of the method as here applied, it has proved impossible to interpret the story in strictly stratigraphical terms.

We have found no evidence within the city of Brisbane for assigning ages either to the Bunya Phyllites or the Neranleigh-Fernvale Group. We do not know the age of either of the two epochs of regional metamorphism, nor do we know when either the St. Lucia Thrust or the Hamilton Thrust took place. Of the several igneous events we can be sure of the age of only the last, namely, the Brisbane Tuffs.

If we seek indirect age determinations through external correlations based on lithology or intensity of metamorphism we are in little better case. On such evidence the Brisbane Metamorphics have, at one time or another, been assigned to practically every period from the Pre-Cambrian to the Permo-Carboniferous. Only with regard to the upper limit of the Brisbane Metamorphics do we find a clue, for they appear to be older than the lithologically distinct, unmetamorphosed, richly fossiliferous Devonian strata that occur both to the north and to the south, although at very considerable distances from Brisbane.

The history of the Brisbane Metamorphics, as far as it can be deciphered within the bounds of Greater Brisbane, is summarised in the table below.

THE HISTORY OF THE BRISBANE METAMORPHICS.

The Probable Sequence of Events.

Stratigraphic.	Geographic.	Tectonic.	Metamorphic.	Igneous.
Ipswich Coal Measures	Local Lakes			
				Brisbane Tuffs
	Part of	Normal Faults		
			Thermal (moderate)	Enoggera Pluton
	continental			Brookfield Volcanics
	land			
Second hiatus				
	mass	Hamilton Thrust	Kinetic (intense)	
		Orogeny	Regional (mild)	Initiation of D'Aguilar Batholith (white quartz veins)
Neranleigh - Fernvale Group	Geosynclinal Sea	Growth of Indooroopilly Anticline		
		Downwarp		
First hiatus	Median Island	St. Lucia Thrust	Kinetic (? intense)	
Bunya Phyllites	Geosynclinal Sea	Orogeny	Regional (moderate)	
Rocksberg Greenstones				Spilitic Extrusions

It is the history of a small part of the great Tasman Geosyncline, and began with intense and sustained volcanic outbursts, largely submarine, which yielded the basic lavas and tuffs which we now know as the Rocksberg Greenstones. While outcropping in only one small area within Brisbane itself, these are developed on a large scale not far to the north of the city boundaries, and may well occur at depth under a large part of Brisbane.

Immediately following the outpourings of lavas and tuffs, prolonged deposition of muds and clays (now known as the Bunya Phyllites) took place. Originally mapped by Denmead as covering a large part of Brisbane, they are restricted in our interpretation to a relatively small triangular area with its southern apex at Indooroopilly.

There followed a pause in deposition during which mild regional metamorphism converted the Rocksberg lavas and tuffs into greenstones and the Bunya muds and clays into phyllites. At about the same time, the first result of prolonged though possibly intermittent pressure from the north-east, was the initiation of the Indooroopilly Anticline which rapidly grew to form a median island in the geosyncline. This lateral pressure reached a first culmination in a great overthrust called by us the St. Lucia Thrust which pushed a sheet of rocks (the St. Lucia Polymetamorphics) over the top of the phyllites. These overthrust rocks may well have been a lateral extension of the Bunya Phyllites, for they are very similar in both texture and composition. The severe deformation resulting from these movements is shown by the crumpling of the micaceous layers into an involved and intricate system of small scale contortions and the crushing of the quartzitic layers into a black ultramylonite.

This first orogenic climax was followed by a quiescent interval during which gentle downwarping took place which, however, may not have completely submerged the median island. The sediments now formed were very different in character from and accumulated far more rapidly than those which had been deposited earlier. They consisted largely of felspathic sands, though muds were well represented. The compaction of these sediments of the Neranleigh-Fernvale Group was followed by a second even milder regional metamorphism which had little effect upon the greywackes beyond further consolidating them, but which was sufficient to turn the shales into slates.

It was at about this time that the earliest of the numerous white quartz veins were emplaced, from which we have inferred the initiation of the D'Aguilar Batholith. Following the appearance of this first generation of quartz veins, the continuing pressure from the north-east reached a second culmination in a second overthrust. This time the rocks of the overthrust sheet came mainly from the north-easterly extension of the Neranleigh-Fernvale Group, though in places the St. Lucia Polymetamorphics were involved to some extent. This appears to have been more complex than the earlier thrust, many minor offshoots from the main thrust plane producing an imbricate structure, and in places where the thrust plane was close to the top of the Polymetamorphics, the latter were scooped up and carried to the surface. The rocks which were affected by this second thrust alone we have called the Hamilton Cataclasites. Being in the main coarser than the earlier sediments, the structures produced in them are generally on a larger scale. Some of the white quartz veins were involved in this second thrust and violently disturbed, while others, such as the "bedded" veins, though not deformed were optically strained.

The Indooroopilly Anticline had now reached such a height that the whole of Brisbane was converted into a land area. On parts of the surface the acid lavas and tuffs, now restricted by denudation to the Brookfield area, accumulated.

The final stage of the D'Aguilar Batholith followed, namely, the forcible injection of the Enoggera Pluton, which in its crosscutting character was in contrast to the earlier phases which may well have been concordant.

SUMMARY.

This paper proposes the division of the Brisbane Metamorphics into an earlier more-metamorphosed group, consisting of the Rocksberg Greenstones and the Bunya Phyllites, followed unconformably by a younger less-metamorphosed Neranleigh-Fernvale group.

This complete structural history involves five principal episodes as follows:—1. A first regional metamorphism which affected the whole area occupied by the older group. 2. A first or St. Lucia thrust which added some purely kinetic effects to that part of the Bunya Phyllites involved. 3. An orogeny accompanied by a second very mild regional metamorphism, subsequent to the deposition of the younger group, which added little to the metamorphism of the older group but which produced noticeable effects on some members of the Neranleigh-Fernvale Group. 4. A second or Hamilton thrust that changed still farther those parts of the older group which came under its influence, converting them to the most intensely affected of the St. Lucia Polymetamorphics and crushing parts of the younger group into the Hamilton Cataclasites. Accompanying the Hamilton thrust was the important Buranda Tear Fault which brought about a horizontal displacement of the Neranleigh-Fernvale Group of approximately seven miles. 5. Finally, a series of near-strike tensional faults sliced the Brisbane Metamorphics in pre-Mesozoic times.

The paper also deals with the associated and related igneous events.

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EXPLANATION OF PLATES.

Plate I.

Contrasting types within the Brisbane Metamorphics.

1. Banded slates of Neranleigh-Fernvale Group. Upper Brookfield.

2. Contorted Bunya Phyllites with numerous quartz veins. Near Ivory Street, City.

Plate II.

Bunya Phyllites.

1. On the crest of the Indooroopilly anticline as seen through a window in the St. Lucia Polymetamorphics. Slide No. 1508, U. of Q. Colln. × 15.

2. River Road, Indooroopilly.

Plate III.

Macroscopic effects of the Hamilton Thrust.

1. Gouge occupying a minor thrust-plane (outlined in white). St. Lucia Road, Toowong.

2. White quartz vein showing thrust and normal faults. St. Lucia Road, Toowong.

Plate IV.

White quartz veins affected to different degrees by the Hamilton Thrust.

1. ''Bedded'' quartz. Optically strained but undeformed. Hawken Drive, St. Lucia.

2. Overfolded quartz vein. St. Lucia Road, St. Lucia.

3. Violently deformed quartz veins. Milton Road, Milton.

Plate V.

''Black quartz'' and white quartz in the St. Lucia Polymetamorphics.

1. Vein of strongly sheared pure white quartz, cutting finely grained ''black quartz''. Upland Road, St. Lucia. Slide No. 2915, U. of Q. Colln. Crossed nicols. × 20.

2. Vein of similar white quartz following earlier shear pattern in ''black quartz'' which has been partially replaced. Upland Road, St. Lucia. Slide No. 2915, U. of Q. Colln. × 25.

3. Irregular veins of white quartz invading ''black quartz''. Top of Samford Range. Dr. R. Gradwell's Colln. Crossed nicols. × 20.

Plate VI.

Characteristic patterns in St. Lucia Polymetamorphics.

1. Slip-strain cleavage induced by Hamilton Thrust superseding earlier foliation. Grey Street Bridge. Slide No. 1505, U. of Q. Colln. × 45.

2. Alternations of micaceous bands (black) and ''black quartz'' (dark, finely mottled) invaded by white quartz. Grey Street Bridge. Slide No. 2917, U. of Q. Colln. Crossed nicols. × 40.

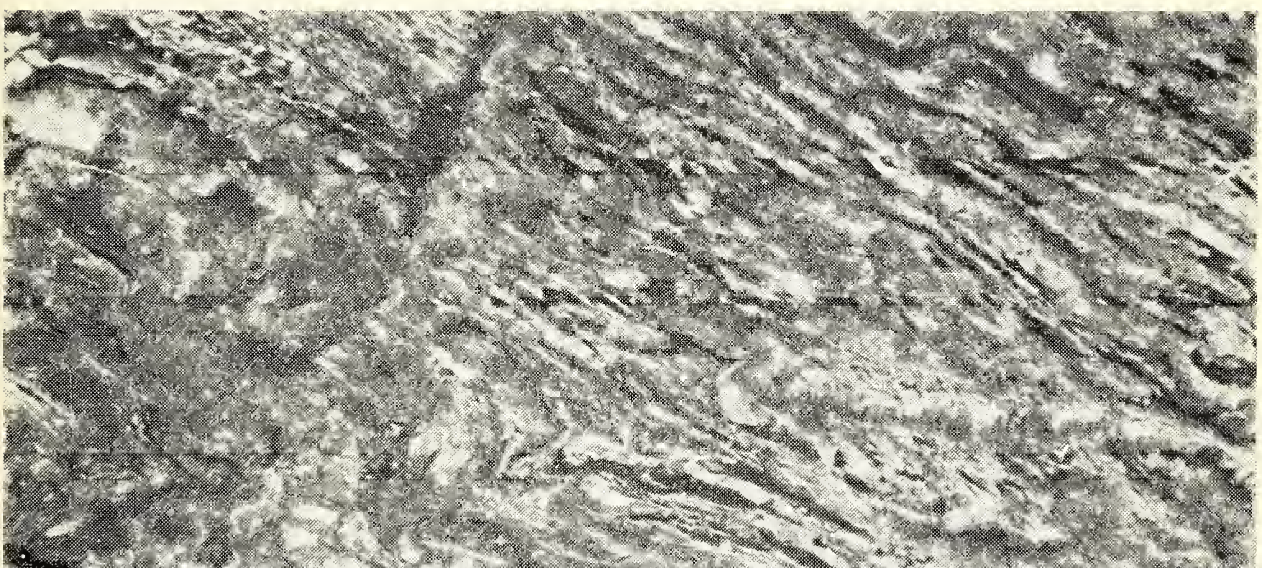
Plate VII.

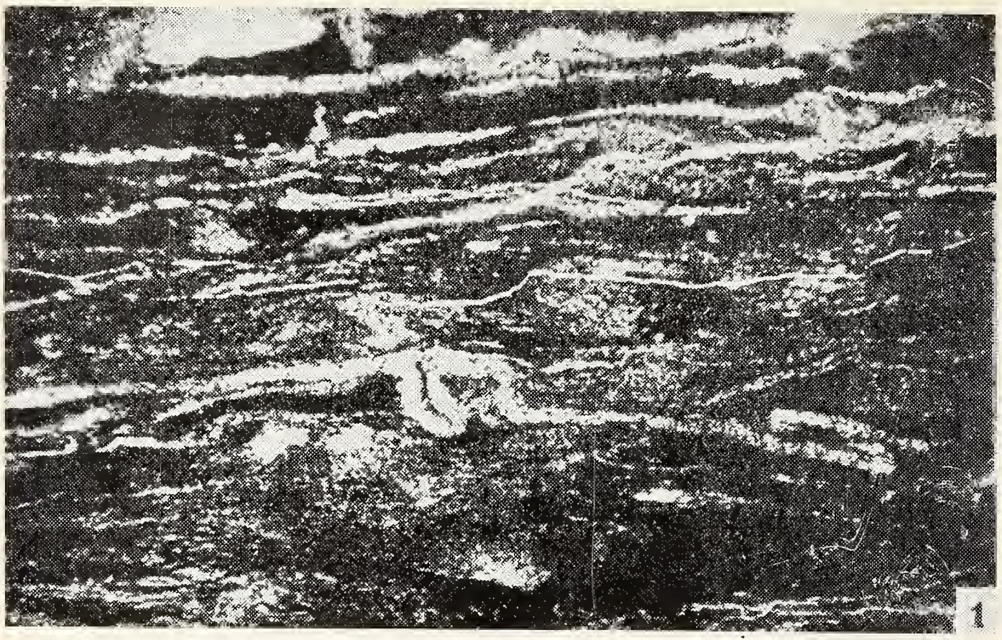
Degrees of deformation in the Neranleigh-Fernvale Group.

1. Typical micro-breccia in psammitic bed of Hamilton Cataclasites. Sewerage shaft, corner of Hamilton Road and Riverview Terrace, Hamilton. Slide No. 1512, U. of Q. Colln. Crossed nicols. × 15.

2. Sheared and contorted mylonite from a nearby pelitic band. Slide No. 2918, U. of Q. Colln. × 20.

3. Similar but undeformed pelitic bed from beneath Hamilton Thrust, Adelaide Street, Brisbane. Slide No. 321, U. of Q. Colln. × 20.





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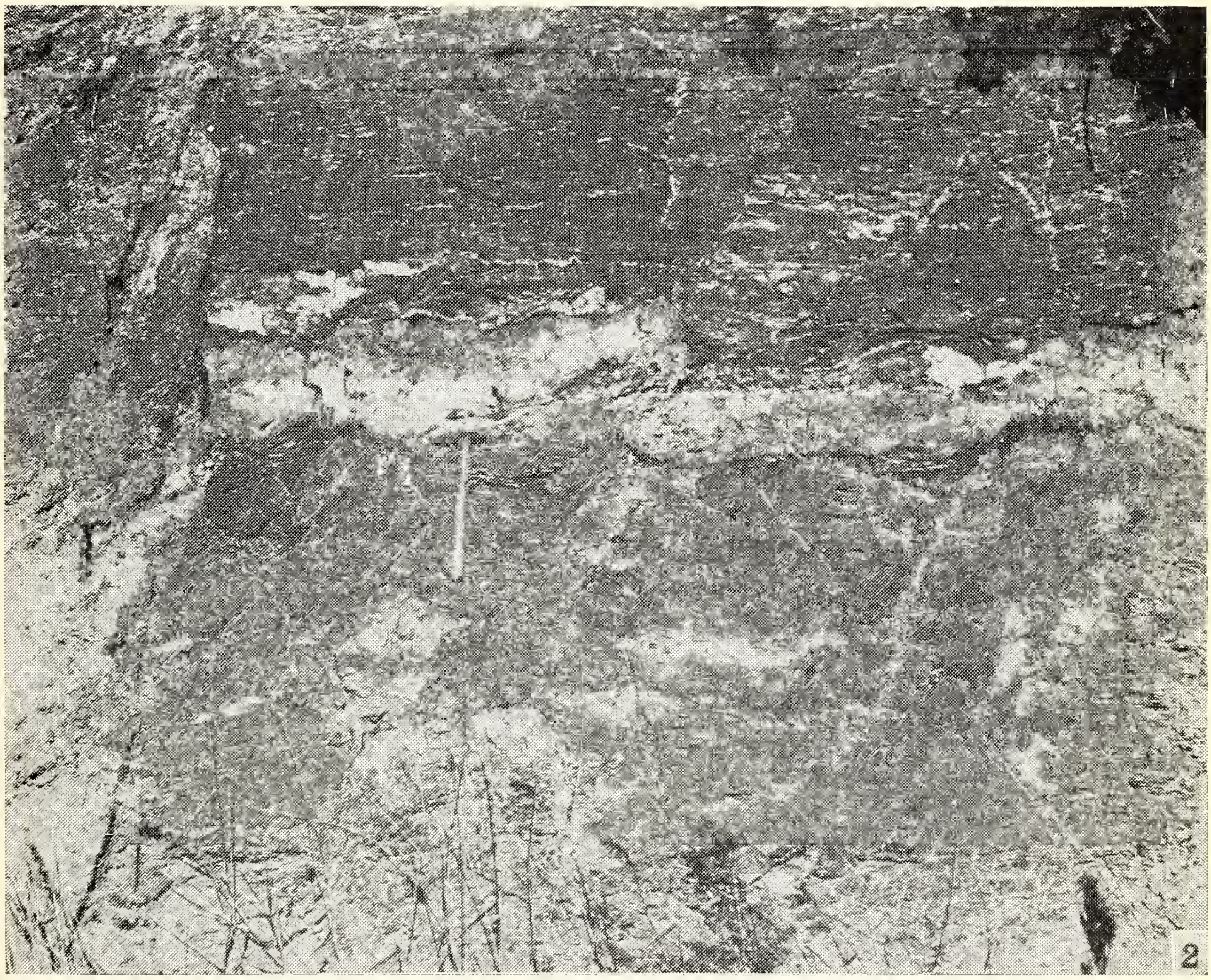

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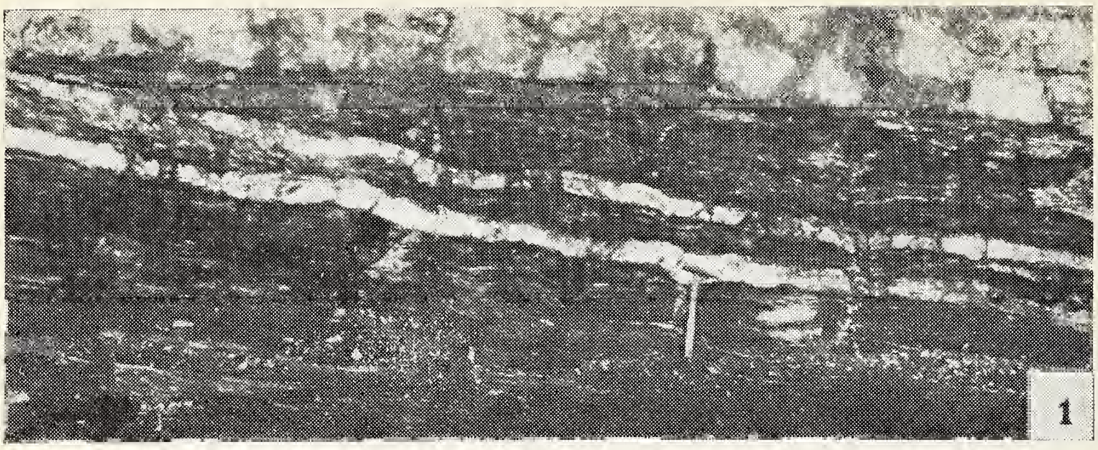

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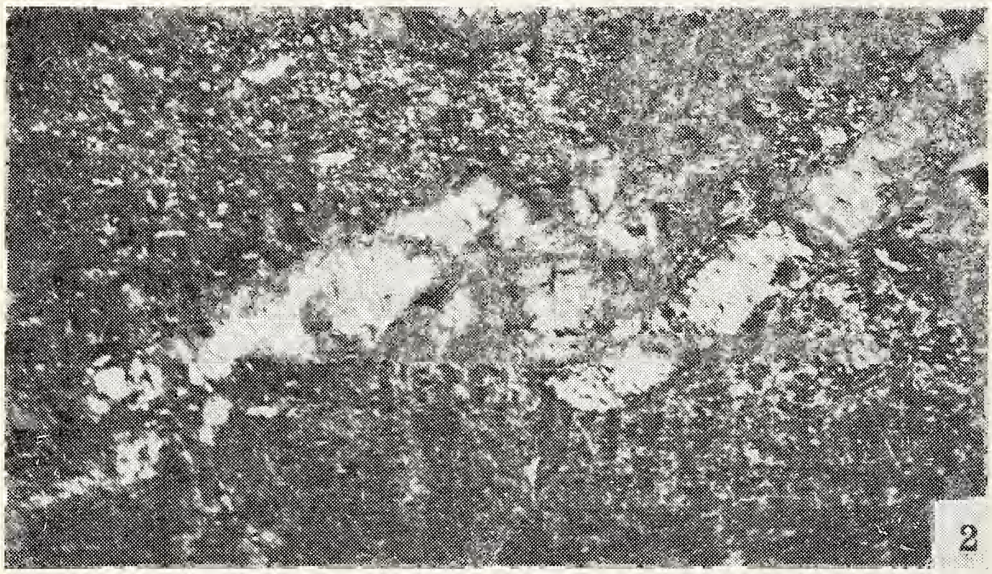

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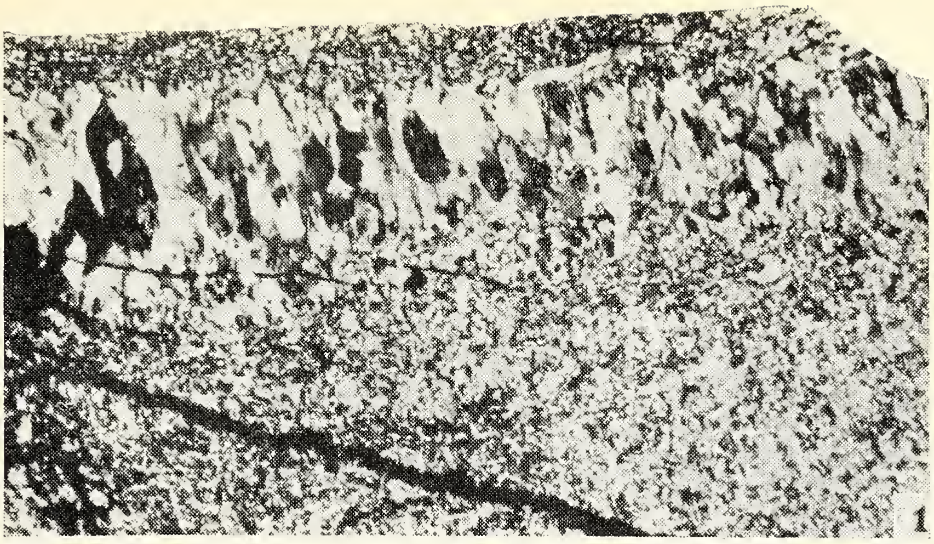

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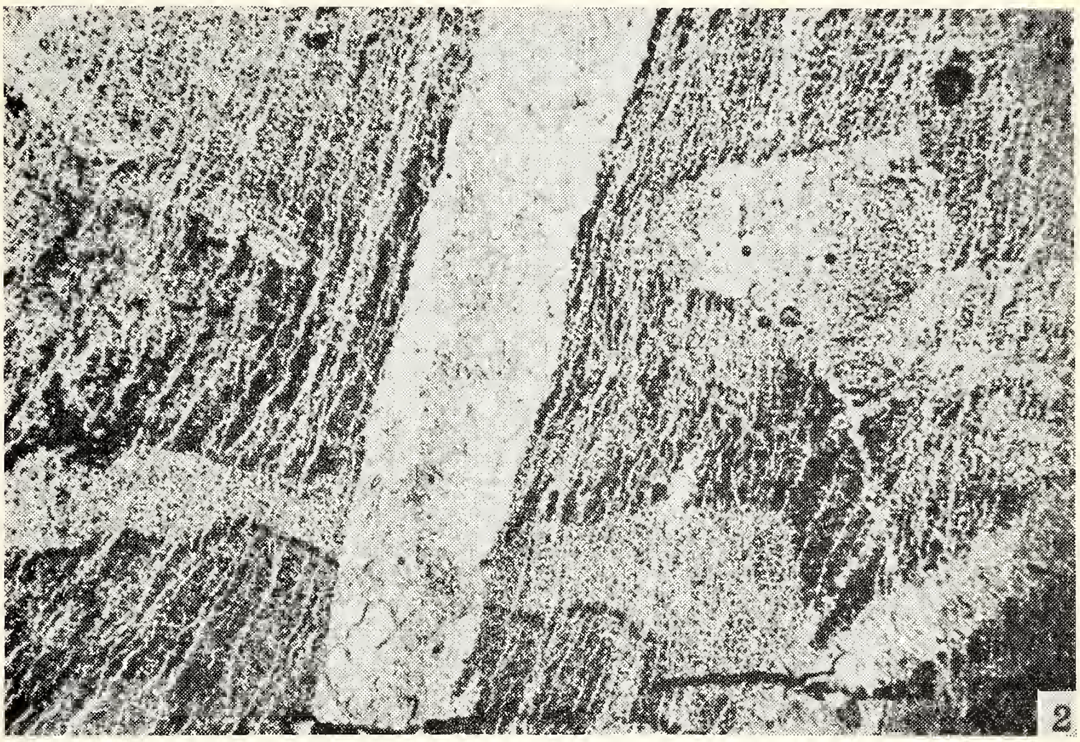

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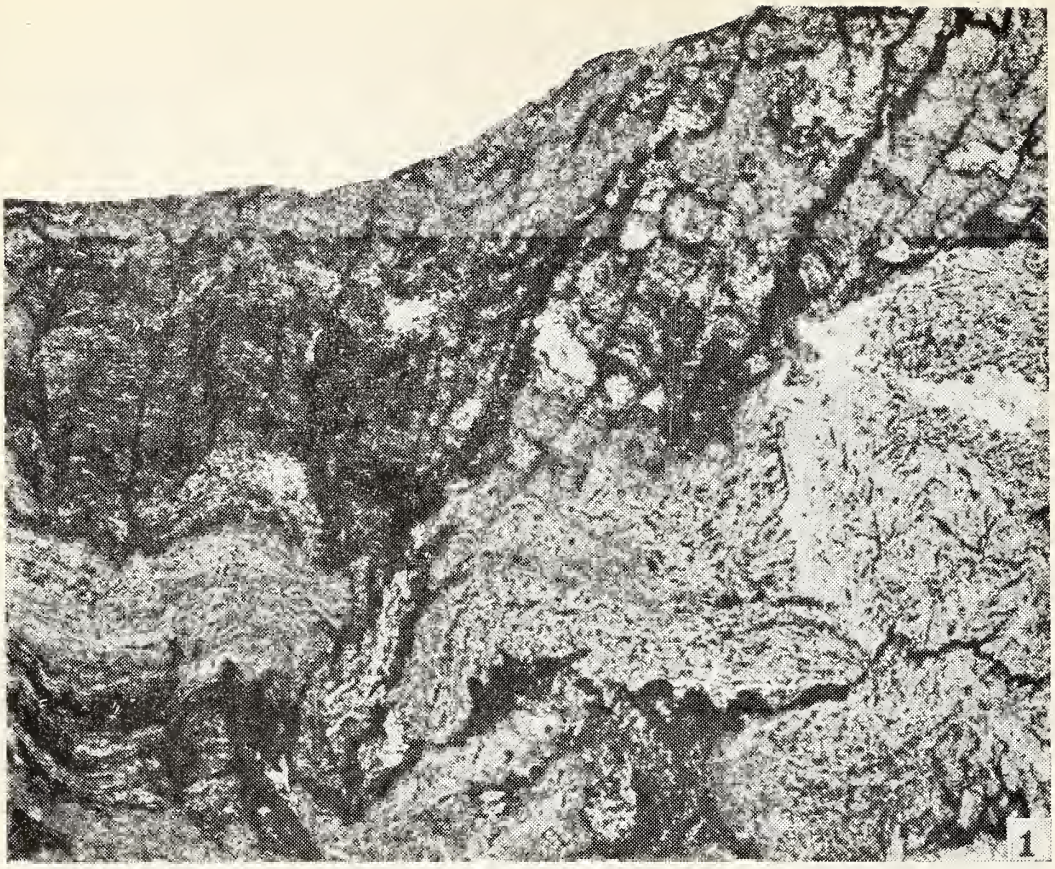

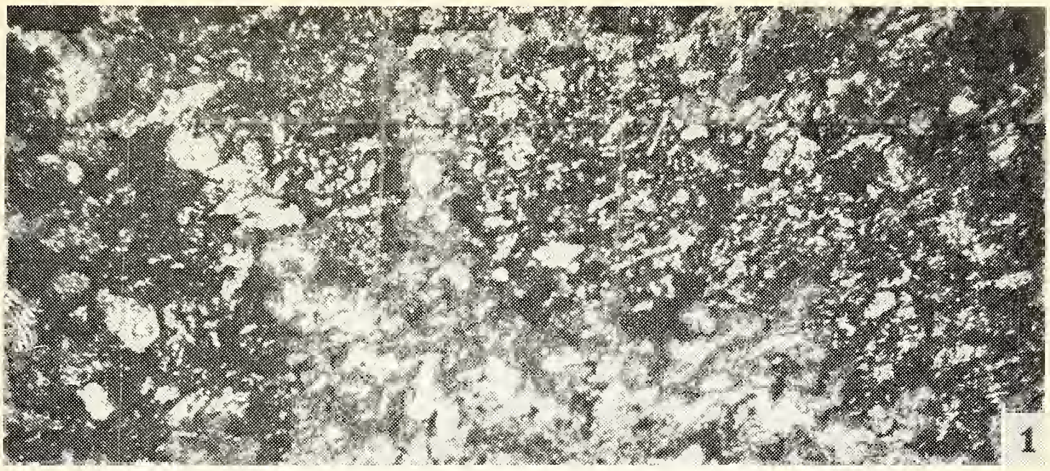

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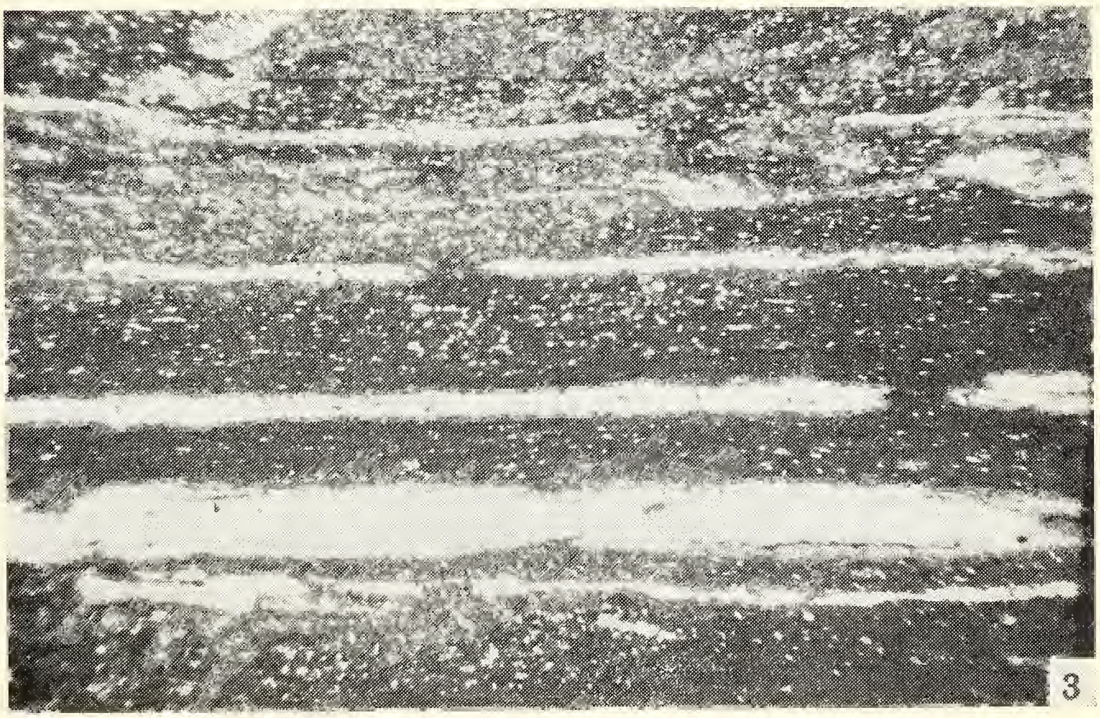

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Vol. LXV., No. 3.

SPHERULITES AND ALLIED STRUCTURES, PART II.

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(With Plates VIII.–XI. and three Text-figures.)

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V. THE SPHERULOIDS OF BINNA BURRA.

(A) Introduction.

From time to time there have been described spheroidal bodies, similar in many respects to spherulites proper, but which depart from the accepted definition of those bodies, in that the spherical form is not the result of radial crystallization from a centre. The containing rocks which are usually of a rhyolitic nature, have been referred to by such terms as "nodular rhyolites", "globular porphyry", "ball rock", "concretionary felstone", "pyromerides" and "roches globulensis", all of which emphasize their outstanding characteristic of sphericity.

The term "spheruloid" was proposed in an earlier paper (Bryan, 1940, p. 41), as an appropriate name for these structures that are at once so like and unlike spherulites. The name connotes no special mode of origin, but aims at emphasizing the resemblance of these forms to spherulites, while recognising important differences.

The following short description by Teall (1888, p. 336) from his classical work on British Petrography is typical of the earlier accounts of these interesting spherical bodies. "Nodular and banded felsites are seen on the south side of Skomer Island. The nodules in these rocks vary in size from minute globules, no larger than small peas, to spherical masses measuring several inches in diameter. They are sometimes solid to the core, at other times they contain a hollow cavity on the surface of which quartz crystals have been formed. A radial structure may occasionally be observed but as a rule it is absent. Bands in the felsite may often be followed through the nodules."

It is not considered necessary to cite further detailed descriptions from the many available in petrographic literature*; suffice it to say that in most of these accounts attention is drawn on the one hand, to the resemblance of spheruloids to the spherulites proper in shape and in mode of occurrence, and on the other hand, to their difference in lacking a dominant radial structure.

Those authors who emphasize the points of resemblance usually claim that the differences are of degree, not of kind, and insist that every gradation may be found from typical spherulites to structureless spheruloids.

But within this school of thought are two divergent views, one of which, represented by Harker (1889), explains these gradations as due to different degrees of weathering and displacement of internal

* For a useful list of references see Greig, (1928, p. 375).

structure, whereas the other view, championed by Greig (1928, p. 375), regards them as different manifestations of spherulitic crystallization.

Those who emphasize the differences between spheruloids and spherulites, consider the absence of radial structure of such great significance that they feel constrained to assign to the spheruloids a quite different mode of origin. But again there are advanced diverse attempts at explanation. Thus von Richthofen (*vide* Harker 1889, p. 32) argued that they were formed by the infilling of vesicles, Tanton (1925, p. 629) regarded them as immiscible globules of glass enclosed within another glass, and Bain (1926, p. 83) suggested that they might be cognate xenoliths (autoliths).

It is possible, of course, that these bodies, occurring as they do in many parts of the world, and ranging in age from Precambrian to Tertiary, have not all been formed in precisely the same way, and that several of the above explanations may be adequate for their individual purposes. On the other hand, spheruloids, the world over, possess so many points in common that it seems reasonable to seek one mode of origin common to them all. Moreover, it is likely that the several different explanations advanced are due to differences of interpretation rather than to differences in the nature of the material studied. In this connection it is significant that, in some cases, as for example in the occurrence at Agate Pt., Ontario (Greig, 1928), several different views as to origin have been founded on examination of the same material.

(B) General Description.

The specimens on which the following description is based have all been obtained from Binna Burra in South-eastern Queensland. They occur in astounding profusion in a sequence of rhyolitic flows totalling several hundred feet in thickness. These rhyolites, felsites, perlites and acid lavas form part of a much greater and more extensive series of volcanic rocks consisting for the most part of basalts and andesites. The rhyolitic flows form a succession towards the base of the series, which is generally regarded as Upper Tertiary in age, but which may well be no later than Oligocene. The volcanic series forms a number of plateaux dissected by gorges and canyons, the rhyolitic representatives often appearing as precipitous cliffs which provide excellent, if somewhat awkward, sections for study. Fortunately differential erosion of the successive flows has, in places, resulted in the formation of shelves which provide a means of access.

The spheruloids occur in countless thousands ranging in size from small beads to giant spheres over three feet in diameter, and showing a wide range of variation in shape, aggregation, and internal arrangement. Nevertheless, the individuals in any one flow usually keep rather closely to a pattern characteristic of that flow. Thus, each of the four groups now to be described was restricted to one particular flow. In descending order these are as follows:

Group 1. The spheruloids are for the most part small, up to about one inch in diameter. Individuals, when they occur, are well rounded with a smooth, glossy surface that readily marks them off from the enclosing rock. Generally they tend to occur as clusters of round individuals, in many cases concentrated along particular fluxion planes so that they appear in vertical cliff-sections like the beads on an abacus. In some cases the individuals forming such a string have coalesced to form a caterpillar-like structure. A further stage in coalition gives rise to platy structures with mammillated surfaces.

A notable feature is that the great majority of these small spheruloids are found half above and half below well-marked flow planes that clearly penetrate them. The upper and lower halves are frequently not quite symmetrical, showing that although growth of both parts started from the same point, the two halves developed independently, but at approximately the same rate. In some examples the two halves meet in a common outwardly projecting flange coincident with the fluxion plane.

Wherever the small spheruloids of this group are found they are extremely numerous; nevertheless, owing to their restriction to well-defined bands, they do not form a very large proportion of the rock mass as a whole.

Group 2. Another cliff face, formed from a lower flow, shows larger spheruloids, for the most part measuring several inches in diameter and reaching a maximum of about one foot. These are scattered sporadically through a groundmass composed of perlitic glass. The members of this group exhibit several remarkable features. They are almost perfectly spherical, and show no sign of mammillated or botryoidal irregularities. Complete individuals are easily collected, for they come away freely and cleanly from the groundmass.

These spheruloids are invariably hollow, each having a single stellate cavity. Fluxion lines may be followed continuously through these spheruloids, but they show definite evidence of disturbance.

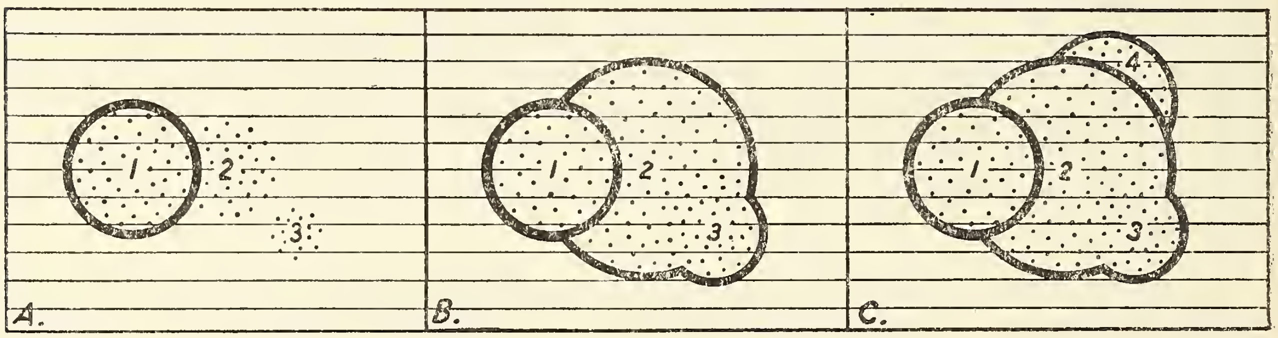
Group 3. This consists of more numerous spheruloids, more closely spaced within the flow. They exhibit a greater range in size than those of the second group, but have a similar maximum diameter of about one foot. Although in a few instances they approach a regularly spherical form, in the majority of cases they are distinctly irregular. Many examples are rough approximations to biaxial or triaxial ellipsoids, the longest axis always being clearly related to a fluxion plane of the enclosing rhyolite. Externally, the members of this group always exhibit, very plainly, the fluxion phenomena of the lava from which they were formed. These features appear as though superimposed on the irregular, warty surfaces characteristic of the group.

Enclosing each spheruloid there is present a distinct crust that differs conspicuously in its darker colour and finer texture from the enclosed material. The thickness of these crusts is very variable, the largest spheruloids usually, but not always, possessing the thickest cover.

The relationship between the nature of the crust and the shape of the enclosed spheruloid is of some interest. In simple spheruloids the crust is regular and of uniform thickness, but in composite spheruloids the thickness of the crust may be variable even in that one specimen, according to the mode of origin of the several protuberant parts.

In one, where the bulbous excrescence is itself part of a small but complete spheruloid of an earlier generation that has been partially engulfed, the protuberance is seen, on breaking the specimen, to have its own complete crust, which may have been thickened in the protuberant part by that of the enclosing spheruloid. (Figure 1, B.1). In a second, the excrescence appears to be part of a spheruloid of the same generation that has coalesced with the larger spheruloid before either has developed a crust. Consequently, whereas the protuberant part is covered by an outgrowth of the crust of the large spheruloid, the inner part shows no sign of an integument of any kind (Fig. 1, B.3). A third kind of irregularity proves to be an excrescence in the strictest sense. It represents growth of a later generation superimposed on the large spheruloid. It is covered externally by its own relatively thin crust, but rests upon the thicker crust of the large spheruloid (Fig. 1, C.4).

All three types may occur in the one specimen resulting in a somewhat irregular composite spheruloid with a warty or mammillary appearance (Fig. 1). The relationship of the three kinds of protuberances to the main spheruloid and more particularly to its crust are shown in Fig. 1, in which the sequence of development is also indicated by the numbers one to four.



Text-fig. 1.—Diagram showing growth and amalgamation of spheruloids. Note that when a skin has been formed, no further expansion of the individual occurs (except as the result of distension).

In one particularly interesting specimen a spheruloid completely enclosed by a dark grey crust has been partially engulfed by another spheruloid of similar size, which is itself contained within a thinner red crust. In this example, as indeed in all cases of these irregular spheruloids, the one set of fluxion planes pass continuously through both spheruloids, together with their protuberances and crusts without interruption or divergence.

In some cases the crusts are sufficiently thick to contain within themselves ovoid patches of material indistinguishable from that of the spheruloid proper.

Separating the conspicuous crusts from the spheruloid within, there is often to be found an inner skin, usually less than 1 mm. in thickness, comparable in colour and texture with the spheruloid itself. The lenses of spheruloidal material enclosed within the thickness of the outer crust also possess this inner envelope. The inner skin may be marked off from both the crust and the spheruloid by thin films of haematite. The inner of these is very regular but the outer is less regular and encloses minor outgrowths of the inner skin.

In some instances the spheruloid appears to have split along the junction of the inner skin with the spheruloid to form a crack which has been partially filled by tridymite.

The spheruloids of this group are never cavernous. On the other hand they are not very dense, a somewhat loose, spongy texture being a characteristic feature.

Group 4. This group is well exhibited in a spectacular section consisting of a cliff face made up almost entirely of large spheruloids measuring up to three feet in diameter. (Plate VIII., Figs. 1-3.) The groundmass, which barely separates these huge spheruloids, forms less than one-fourth of the section and cannot therefore occupy much more than ten per cent. of the whole mass. It consists of a fresh, black perlitic glass.

Some of the spheruloids are quite dense, others are cavernous, and still others are loose textured. Apart from their larger size, these three varieties are very similar to members of the groups A, B and C respectively.

A special feature associated with one of the large hollow spheruloids warrants more detailed consideration. This is the presence in a cavernous spheruloid, measuring about two feet in diameter, of several objects superficially resembling 'stalagmites' that project upwardly from the floor of the miniature cavern (Plate XI., Fig. 1).

Closer inspection shows that the 'stalagmites' are in reality fluted and striated masses of rhyolitic lava that have been injected through irregular cracks in the base of the spheruloid. In the specimen illustrated, the lava has been of such a consistency that it has retained the pattern impressed upon it as it was squeezed through the crack which acted in much the same manner as the dies used in biscuit factories to produce patterns on biscuits of the ribbon type.

The viscosity of the injected lava was not quite great enough to hold the 'ribbon' in an upright position, and as it grew it sagged laterally under its own weight. An examination (Plate XI., Fig. 2) shows that while the cross section of the ribbon of lava progressively increases from the tip towards the base, the details of the pattern remain unchanged. This suggests that the crack which allowed the injection became progressively wider during the process. The somewhat serrated edges of the ribbon are due to a plucking effect brought about by the high viscosity. This feature too is to be seen in many biscuits of the ribbon type. It is not due (as might at first be thought) to spasmodic movement through the die, but solely to the degree of plasticity of the biscuit mixture.

The special significance of these injections into the cavernous spheruloid will be considered later in this paper.

The preceeding descriptions must not be regarded as adequately covering the almost innumerable varieties of spheruloids that may be examined and collected at Binna Burra, but they do indicate the outstanding characteristics. Several remarks of a general nature may be added. In almost all cases the spheruloids are clearly distinct from the enclosing groundmass. The distinction may be shown by differences of colour or texture, and is still clearly to be seen even where the same fluxion lines can be followed from the groundmass, through the spheruloid, and out again into the groundmass. The difference is particularly marked, where, as in many cases, the enclosing rock is a glass, for although the spheruloids show some variety in constitution, they are never glassy. Nor are they spherulitic, for despite the numerous good exposures and the many hundreds of specimens that have been examined, not one example of a spherulite proper has been found.

In spite of their great variety in shape and form the spheruloids show a marked lithological uniformity. In all cases, if a fresh surface be examined, it is seen to be light in colour (pink or cream or greyish) and of a felsitic texture. A considerable number of fresh phenocrysts of quartz and of felspars, about one millimetre in diameter, and an occasional smaller phenocryst of a black ferro-magnesian mineral are set in the felsitic groundmass. Fluxion phenomena are to be seen in all specimens, in some cases quite strongly developed. This usually shows itself as a somewhat indistinct colour banding or streakiness in a texturally uniform rock. The flow planes are clearly influenced by the position and shape of the phenocrysts.

In the solid spheruloids, the flow planes cut right across the specimen, being quite independent of its contours, but in hollow spheruloids they show the influence of the external form and exhibit curves that, while they are not quite concentric with the margin of the spheruloid, are in harmony with it.

(C) Microscopic Features.

The regular nature of a spheruloid and its marked differences from the immediate surroundings give it an appearance of completeness and unity that leads one to expect a simple and homogeneous internal structure, or at least, a systematic arrangement of the mineral constituents. But this expectation is not realised. Mineralogically, each spheruloid is a heterogeneous aggregate, and such structures as do exist are independent of each other and discordant with the complete structure of the spheruloid. Moreover, the interior does not represent either a simple simultaneous crystallization or an orderly sequence of events, but appears to result from the integration of different minerals and different structures developed at different stages of a somewhat complex history.

From this point of view, the ingredients of a spheruloid fall for the most part into three distinct groups. First, there are the relatively large but sporadic crystals forming the phenocrysts. Secondly, there are those minerals found associated with, and indeed contributing to, the fluxion phenomena, while in the third group may be placed those minerals the attitude and arrangement of which is strikingly independent of the fluxion.

1. The Phenocrysts.—The phenocrysts quite clearly belong to an early generation of their own and can have little to do with the development of spheruloids as such, for they occur as freely in the enclosing glass as in the spheruloids themselves. The most abundant phenocrysts are those of sanidine. These vary in size from one-half to two millimetres. They are invariably clear and colourless with no sign of decomposition. They are rarely idiomorphic, but in many cases show marked embayments. In some cases, the whole surface of the crystal appears to have suffered resorption. Carlsbad twins are shown by some crystals. The two characteristic cleavages, although perfectly developed, are not conspicuous. A noticeable feature is the presence of inclusions arranged in parallel planes coincident with one of these cleavages. The phenocrysts of sanidine show a definite influence on the course of the flow planes which sweep about them. In some cases the crystals are orientated with their long axes parallel to the fluxion. Occasionally, such crystals are seen to have been cracked and the two broken fragments drawn asunder so that the cracks have become rifts with parallel walls.

The phenocrysts next in abundance are those of quartz. These are usually less than one millimetre in length and are for the most part idiomorphic. They occur as bipyramidal crystals giving rhombic sections parallel to the vertical axis. In a very few instances the prism is also present but poorly developed. In contrast to the phenocrysts of sanidine they show little or no sign of embayment.

Far less common than either the sanidine or the quartz are phenocrysts of acid oligoclase. These are usually idiomorphic, or nearly so. They show both carlsbad and albite twinning. Ferro-magnesian phenocrysts although present are far from plentiful. They consist for the most part of occasional small crystals of biotite.

2. The Minerals Influenced by Fluxion.—The phenocrysts described above are surrounded by minerals which by their distribution and arrangement clearly reflect the fluxion phenomena, and obviously represent a later crystallization than that of the phenocrysts. The most important mineral of this group is a felspar (presumably orthoclase) which occurs as numerous small elongate crystals arranged in sub-parallel fashion. In ordinary light it is difficult to distinguish these from their surroundings owing to their clarity, freshness and the lack of refractive contrast, but under crossed nicols they are exhibited as clear-cut crystals with elongate rectangular sections in the direction of flow.

In a few of the slides examined the fluxion phenomena are also emphasized by very numerous minute crystals of a greenish ferro-magnesian mineral. These are arranged in swirling groups of sub-parallel crystals that sweep about the phenocrysts. Within the narrow spaces between adjacent phenocrysts they are crowded together as though constricted owing to their having been forced through a strait.

In addition to the above minerals, many slides clearly indicate the fluxion by the arrangement of numerous crystallites. These are contained within the thickness of the slide and consist chiefly of trichites, margarites and longulites, the last two of which show in their orientation a definite parallelism with the flow planes.

3. The Minerals Independent of Fluxion.—In striking contrast with the previous group are those minerals that are quite independent of the flow phenomena in their attitude, arrangement and distribution, and they appear to have crystallized after all other movement had ceased. Nevertheless, their distribution is not sporadic nor is their arrangement haphazard. These, too, appear to have developed in accordance with a definite plan, but it is a new plan.

The most notable development of this group is seen in the ferro-magnesian minerals. These may consist of individual microlites arranged in roughly parallel fashion, or they may take the form of connected groups, but always their orientation is discordant with that of the flow planes. In some cases the arrangement consists of a number of elongate delicate microlites or slender crystals springing from a common point, and although diverging somewhat, all point in the same general direction. In other cases, the group may diverge by dichotomous branching from an initial individual, but the general effect is much the same. All the bunches in any of the slides examined are orientated along the same general line and diverge in the same way. The whole slide thus appears to be pierced by a delicate tenuous structure of slender ferro-magnesian crystals. The point of origin of any of the divergent bundles may be situated within a particular flow plane or in some other favourable position such as the embayment of a phenocryst. The distal ends of the constituent crystals of the growing aggregate are seen, in some instances, to have ceased their forward growth quite abruptly where each of the crystals of a group reached a particular flow plane. This influence of flow planes in initiating and terminating growth is in marked contrast to their lack of influence in the matter of orientation. Where a group of these crystals encounters a phenocryst it tends to splay out about the phenocryst in further growth.

In a few isolated instances the femic mineral is arranged in roughly radial clumps of somewhat stouter but shorter crystals. These larger crystals show that the mineral is greyish-green in colour, strongly pleochroic, with high interference colours and an extinction angle at or very near the zero position. These optical properties are in keeping with those of a ferro-magnesian mica, but if so they are difficult to reconcile with the capillary habit of the smaller crystals.

4. Other Minerals.—Although, owing to their equidimensional shapes, they show no sign of regular arrangement sympathetic to either the parallel felspars of the flow planes or the divergent aggregates of the ferro-magnesian mineral, there should be mentioned the numerous minute crystals of quartz which make up a large part of the ground-mass.

In some of the slides the appearance of heterogeneity is emphasized by the presence of occasional and obviously incidental microspherulites. These are dusty from decomposition, ragged in outline and up to one millimetre in diameter. They occur sporadically and are usually associated with the phenocrysts. In one example a phenocryst has been cracked transversely, the parts have been drawn asunder, and in the rift thus formed an irregular spherulitic growth has been initiated which has travelled to the outer limit of the rift and there spread out fanwise to form a hemi-spherulite. This example shows that the spherulites were produced after the lava had become quite viscous, but before the felspars of the ground-mass had crystallised. The micro-spherulites when present thus appear to be intermediate in time between the first and second groups discussed above.

(D) Chemical Considerations.

In order to establish the chemical relationship of the many varieties of spheruloids at Binna Burra to their respective parent rocks a large number of analyses would be necessary. Only with such a complete chemical record would it be possible to make, with confidence, generalisations covering the whole range of phenomena observed. But since such a comprehensive set of analyses was not available and could not be specially prepared for this paper, recourse was had to the selection and analysis of one spheruloid and of the rock in which it was embedded. In selecting the material for analysis every endeavour was made to assure that it was typical, as far as such a thing is possible in a series with so many variants, and that it was unaffected by weathering.

The material chosen consisted of a fresh, grey glass with pronounced perlitic structure, containing well-developed hollow spheruloids ranging in size from about a half-inch to two inches in diameter, all of which still retained traces of the initial central vesicle. Part of the specimen from which the samples were obtained is shown as Plate X., fig. 1. Microslides prepared for the purpose showed that, compared with other specimens neither the containing glass nor the spheruloid presented any unusual or abnormal features.

TABLE I.

ROCK ANALYSES FROM BINNA BURRA, QUEENSLAND, AND FOR PURPOSES OF COMPARISON, FROM AGATE POINT, ONTARIO.

—	Binna Burra.		Agate Point.	
	Perlitic Glass.	Spheruloid.	Red Vitrophyre.	Black Orbs.
SiO_2	71·70	72·00	71·64	76·20
Al_2O_3	14·14	14·93	13·19	11·33
Fe_2O_3	0·56	1·41	2·39	1·90
FeO	0·46	0·32	0·18	0·28
MgO	0·09	0·10	0·25	0·20
CaO	0·40	0·40	1·17	0·92
Na_2O	4·28	5·46	2·41	2·75
K_2O	5·16	3·74	3·85	3·42
H_2O+	3·40	1·20	2·28	1·81
H_2O-	0·10	0·80	2·00	0·28
TiO_2	—	—	0·31	0·34
MnO	0·05	0·05	—	—
Volatile	—	—	—	0·56
Totals	100·34	100·41	99·67	99·99

The perlitic glass from Binna Burra which envelops the spheruloid is shown by an analysis to have no striking or abnormal features. Calculation of the norm shows the rock to be a Liparose with the symbols (I. 4.1.3). Rhyolitic rocks of such a type are quite common in South-eastern Queensland as is shown by the fact that four of the nine analyses of rhyolites, pitchstones, etc. selected by Richards (1915, p. 142) as typical of South-eastern Queensland are included in the Liparose sub-rang. In particular the perlite is chemically similar to the rhyolitic glasses of Mount Lindesay and the MacPherson Range. These are not very distant from the Binna Burra material and are almost certainly coeval with it. In short, the glass seems quite normal.

The analysis of the spheruloid from Binna Burra (treated on its own merits, and without reference to that of the enclosing glass), is of a kind less common in South-eastern Queensland. Its norm brings it within the sub-rang Kallerudose (I. 4.4.4.). Only one such rhyolite is listed by Richards (1915, p. 142) from Glen Rock, Esk, and this is abnormal in other respects, too.

A comparison of the analysis of the perlite with that of the spheruloid presents some expected features and others that were not anticipated. In the former category may be placed the close resemblance in silica, alumina, magnesia and lime. Such similarities support the conclusion that the spheruloids were formed *in situ* from material similar to that which provided the enclosing glass. Certain of the differences shown by the two analyses were also expected. Thus the relatively smaller content of H_2O+ in the spheruloid was anticipated in view of the hypothesis (to be advanced later) that the expansion exhibited by the hollow spheruloid was due to the effect of steam set free by crystallization within the spheruloid. Assuming that the water content of the two materials was initially equal, then 2·2% (that is about 65% of the original H_2O+ of the spheruloid) has been converted into steam. But, if the suggestion that hollow spheruloids tend to be formed in the wetter parts of the lava be accepted (and the presence of central vesicles supports such a view), then considerably greater quantities of water must have been lost in the subsequent expansion.

The relatively higher ferric oxide in the spheruloid, while it was not anticipated, may be explained as due to the oxidation of the exposed segmental surfaces since consolidation and disruption. The fact that the segments are coated by a yellow inorganic stain is in keeping with such an explanation.

The most unexpected feature in the analyses is the discrepancy in the relative proportions of soda and potash. Whereas the total alkalies are closely comparable, the glass shows a definite excess of potash, while the spheruloid shows just as definite an excess of soda. Such a discordance indicates unexpected sudden variations in composition of the parent lava, and the question naturally arises as to whether the spheruloid was produced as a result of the locally high soda-potash ratio. Since it would be unwise to base such an important conclusion on one pair of analyses only, and in the absence of any further chemical evidence from the local material, we may study the results obtained elsewhere.

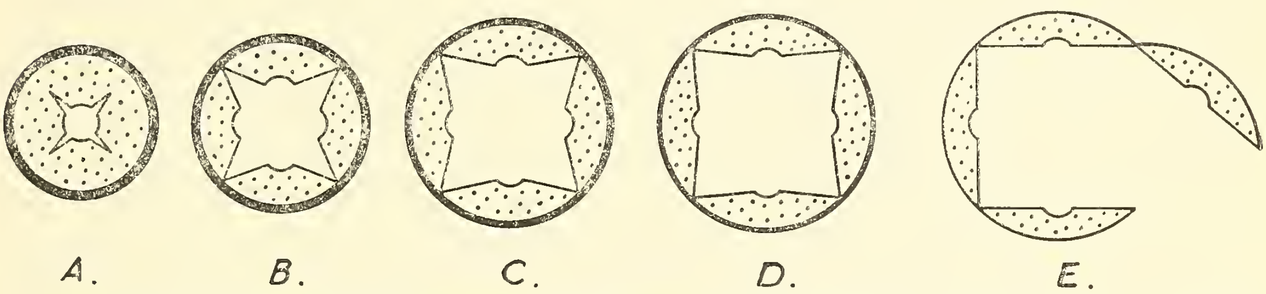
At the occurrence already mentioned at Agate Point on the shores of Lake Superior, Bain (1926, p. 82) has collected and analysed black "Orbs" (similar in many respects to our spheruloids) and the containing red rhyolitic glass. Bain's analyses are set out in Table I. of this paper, for comparison with the Binna Burra material. A glance at the analyses from Agate Point shows that not only are the total alkalies of the orb similar to those of the glass, but the proportions of soda to potash are not very dissimilar, although here, too, the spheruloid is somewhat richer in soda than is the groundmass. If, as seems probable, the Agate Point material is to be regarded as comparable in general to that obtained at Binna Burra, these facts would suggest that the development of spheruloids is not determined by a local excess of soda over potash, but nevertheless, a local enrichment in soda, even a small amount, may possibly predispose a portion of the lava towards spheruloidal growth.

(E) Hollow Spheruloids.

Many of the broken spheruloids that lie scattered upon the slopes of Binna Burra, and a large proportion of those collected *in situ* for examination, show the presence of a hollow interior closely resembling those found in the nodular spherulites of Tamborine Mountain (Bryan, 1934, p. 168). These cavities vary in size from minute hollows to cavernous openings nearly three feet in diameter (Plate VIII., fig. 3). They vary, too, in size relative to the spheruloid that contains them. In some spheruloids the cavities form only a small proportion of the total, while in others the solid material is little more than an enclosing skin. One noteworthy fact is that, the larger the cavity relative to the spheruloid, the more nearly does the latter approach true sphericity in its outer surface.

In shape, too, the hollow interiors show considerable variety; nevertheless, a large proportion of them present a markedly regular appearance, and in a great many cases, even show a close approach to certain well-defined geometrical patterns.

There appears too to be a definite relationship between the shape of the cavity and its size relative to that of the complete spheruloid. In general, relatively small cavities are acutely angular, whereas relatively large cavities are less deeply indented. In a great number of instances the cavities present more or less regular stellate cross sections, the result of each spheruloid being divided into a number of radially arranged sectors, each with its narrow end directed towards the cavernous interior. The number of such sectors has a wide range and may be as small as four, or as great as twenty-four. Adopting the argument adduced in Part I of the paper (Bryan, 1940, p. 46), it can be shown that the ideally symmetrical arrangement consists of twelve sectors based on a pyritohedral pattern. Such a development is not infrequently seen and is responsible for the numerous cross sections showing five sectors in the one plane. Another common arrangement, and one of special interest, is based on the cube and consists of a total of six inwardly projecting sectors, each squarely pyramidal in shape (Fig. 2).



Text-fig. 2.—Diagram showing distension and ultimate rupture of a mature spheruloid.

In very many spheruloids a central vesicle is to be seen. In some cases this is preserved entire, attached to the inner end of one of the segments (See Plate X, Fig. 1). In other cases it has been broken and is represented discontinuously by concave surfaces at the inner ends of all or several sectors.

A notable feature that is to be seen in many hollow spheruloids is a system of radial striae or flutings decorating the broken surfaces of the sectors (Plate X, Figs. 2 and 3). These, on account of both their nature and location, closely simulate the radially arranged felspar fibres characteristic of true spherulitic structure. Closer examination soon reveals, however, that the markings are quite superficial, being restricted to the surfaces of the sectors. They are in no sense spherulitic, but are fracture patterns such as are produced by the tearing apart of highly viscous material.

A smaller number of specimens show, in addition to the radial flutings and disposed at right angles to them, another pattern consisting of a series of concentric interruptions producing small steps in the otherwise even slope of the sectors. They are probably due to the spasmodic nature of the tearing process (Plate X, Fig. 2).

Finally, reference should be made to the fact that in many of the hollow spheruloids, the sectors are coated with a veneer consisting of minutes plates of tridymite. It is of interest to note here that loose-textured spheruloids in no instance possess a central vesicle, nor do they develop hollow interiors.

(F) Origin and Growth of Spheruloids.

There are many features exhibited by the spheruloids of Binna Burra that call for explanation, but outstanding above a host of minor problems, are three of major importance, namely.—(1) the manner of origin, (2) the reason for the adoption of the spherical form, and (3) the nature of hollow spheruloids. These three problems are intimately related, but an attempt will be made in the first instance to deal with them separately.

1. Mode of Origin. In order to clear the ground, a number of explanations, that have been advanced from time to time for similar bodies elsewhere but are inadequate so far as the Binna Burra material is concerned, will be dealt with briefly and summarily dismissed.

Spheruloids are not due (*a*) to the weathering and replacement of true spherulites, for in the great majority of cases they are quite fresh and show no trace of radial structure. The fact that the same fluxion planes are common to the spheruloids and the adjacent groundmass and can be traced continuously from one to the other indicates that the spheruloids cannot be (*b*) infillings of vesicles, (*c*) xenoliths introduced from some outside source (such as bombs from a nearby vent), (*d*) autoliths consolidated at an earlier stage and carried bodily in the lava stream. They are not (*e*) immiscible globules of glass enclosed within another glass. They do not represent (*f*) patches of the surrounding glass that have been devitrified, for the evidence of viscous lava injected through cracks in hollow spheruloids shows that the latter were solid units before the enclosing lava became a glass. Nor does it seem probable that they represent (*g*) regions of the lava that were first vitrified and then devitrified before the vitrification of the surrounding lava.

The only remaining alternative appears to be (*h*) that the spheruloids developed as crystalline aggregates, in the positions they now occupy, before the vitrification of the enclosing lava took place. Such an hypothesis not only avoids the several difficulties that confront the other attempts at explanation but satisfies fully all the field and laboratory evidence that has been assembled.*

2. Adoption of the Spherical Form. Numerous observations indicate that, if undisturbed, a growing spheruloid spreads uniformly outwards in all directions and thus develops and maintains a regularly spherical form. The approach to sphericity is so close and the outer surface so regular and clearly defined that it is natural to enquire as to the nature of the mechanism which guides and regulates this outward growth.

Spherical aggregations of crystalline material can, in general, be brought about in several ways. One method, commonly seen in concretions, is due to the deposition of successive, concentric layers about the initial point. But the entire absence of any trace of concentric structures in the vast majority of cases, either in the hand specimen or under the microscope, shows that this method of growth is inapplicable to the spheruloids.

Orbicular structures due to reactions between a magma and its xenoliths are also essentially concentric in build, and as such these too are ruled out.

* The arguments on which this conclusion is based should be compared with those set out by Greig (1928, p. 383) most of which are directly applicable to the Binna Burra material.

Spherical aggregations may also be due to regularly radial growth about a point. Such is the case in spherulites proper. But the principal reason for introducing the new term 'spheruloid' for the bodies now under discussion was that the shape was not determined by such radial growth. It is true that microscopical examination shows that within some large spheruloids, some spherulites may occur. But these latter are relatively so few, so small, and so widely spaced when they are present, that in volume they form only a small fraction of one per cent of the whole spheruloid. Moreover, the distribution of these microspherulites is so sporadic that they can have no significant relationship to the complete structure. Indeed, in appearance and arrangement, they are so obviously incidental, they serve to emphasize the point that the form of the spheruloid as a whole is not due to any such spherulitic growth.

Another method by which a crystalline aggregate may take on a spherical shape is really a modification of that which we have just considered. This consists of radial crystalline growth building an open skeletal network or scaffolding which is subsequently filled by further crystallization which may or may not be spherulitic. This method has been suggested by Iddings (*vide* Harker, 1889, p. 34) for the origin of some spherulites. He described the process as follows: "In the still viscous glass, from a centre of crystallization the first frail beginnings of felspar spread innumerable rays, pre-empting as it were a sphere of the magma."

Although, in the spheruloids under discussion, felspar is never found in this form, yet, in many of the slides examined, a ferro-magnesian mineral occurs in divergent, fragile, but rigid groups of acicular and capillary crystals, which increase in number dichotomously. It would seem possible on the evidence of these slides that, at least in some cases, small quantities of this ferro-magnesian mineral, crystallizing as an open, many-branched spherulite, might pre-empt, in Iddings' sense, a region subsequently occupied for the most part by a quartz-felspar aggregate. In some of the slides studied the individual crystals were so very fine that the possibility suggested itself that the tenuous framework might be present in other specimens in sub-microscopic form.

For this open spherulitic structure to produce the spherical form by radial growth, the arrangement would have to be developed about one central point. But the evidence of the material examined shows that the growths under consideration have developed not about one but about many points within the spheruloid. In particular, several divergent groups may be seen to radiate from embayments in the sporadically scattered felspar phenocrysts. Again it can be shown that the radial growths are not all continuous to the margin of the spheruloid, for certain groups are sharply limited by fluxion planes within the spheruloid.

Hence, although the writer is of the opinion that these divergent growths may prove to be significant structures in the spheruloids (especially as contrasted with the incidental microspherulites of felspar previously considered), it is difficult to see how they could contribute towards either the unity or the external shape of spheruloids.

The above considerations suggest that the spheruloids do not possess in themselves any structure, concentric or radial, adequate to explain their characteristic sphericity. Greig (1928, p. 398) appears to have been forced to a similar conclusion for the Agate Point material for he writes: "Whether or not there has always been some spherulitic growth radial with respect to the whole 'globule' I have no means of knowing. It is possible that in some cases there has never been any such growth; but that the spherulite was composed of a mass of small bundles of plumose crystals radiating from centres throughout it . . . . The reasons for such growths assuming a spherical form are difficult to see but they are probably the same as for the spherical forms of certain spherulites [*sic*] in artificial glasses which show no radial arrangement."

But if the spheroidal shape is not dependent on internal structures, there remains the possibility that it may have been induced by some process that preceded the development and determined the limits of spheruloidal crystallization. In this connection one is reminded of the position reached by Cross (1891, p. 439) from his study of the spherulites of Colorado. "The idea" he wrote "that a radiate crystallization is the direct and primary cause of the peculiar forms assumed by spherulites cannot be accepted for all cases, because there are instances, ... in which the crystalline growth is very subordinate to an amorphous matter that in its development brings out the same characteristics of form, as opposed to the surrounding glass.

In certain spherulites one finds indications that the form was outlined by the amorphous substance before crystallization began. Further, there are many minor peculiarities . . . . best explained by the assumption of some force tending to produce the spherical form other than that of radiate crystallization."

This preliminary and, as Cross would have it, "more important act", which provided the conditions necessary to spherulitic growth and directed and limited it, was conceived to be "a local change in the character of the magma, in that, within the area of each spherulite, there first developed a colloidal substance." Although the Cross hypothesis of "spheres of influence", as we may perhaps call it, appears gratuitous with respect to many spherulites (for there is ample evidence that these crystallize out immediately without any intervening process, and their external shape consequently is due directly and solely to their mode of growth), it has certain very attractive features where spheruloids are concerned.

But the study of the Binna Burra material suggests that certain elaborations of this simple scheme are necessary if all the phenomena of growing spheruloids are to be covered. Thus, instead of regarding each sphere of influence as fixed in size and position from the beginning, it is more helpful to regard it as continuously spreading outward from an initial point or vesicle, the consequent crystallization almost keeping pace with the expansion of the space. While this progressive occupation of the expanding sphere is in progress, there would appear to be no effective skin or diaphragm surrounding the spheruloidal material, for neighbouring growths readily coalesce. But when the sphere of influence has reached the maximum size which the local conditions allow, and the crystalline aggregate has completely occupied this, a skin of amorphous material is formed about the completed spheruloid. This effectively prevents any further growth of that individual except by inflation and distension.

At this stage, each spheruloid might be regarded as forming a closed system and any further development would be that of a unit independent of the surrounding lava, except in so far as the lava formed a confining medium with certain relevant physical characters such as temperature and viscosity.

In terms of the modified hypothesis it would appear that after initiation (as a spherical droplet?), spheruloids attained their shape by the occupation of a continuously expanding sphere within which conditions were favourable for crystallization.

3. Formation of Hollow Spheruloids. The whole arrangement in a typical hollow spheruloid is just what might be expected in a thick spherical shell that has failed under internal pressure. Mechanical considerations show that in such a case there will be compression directed radially outwards, combined with tangential tension greatest at the inside and least at the outside. Such a combination of forces would tend to produce the outward displacement of wedge-shaped sectors, together with, as a complementary effect, the formation of radial rifts, widest at the inside of the shell and tapering towards the outside. All the features considered earlier, in the description of hollow spheruloids, are consistent with such an hypothesis of internal compression.

The source of the compression which provided the motive power that produced hollow spheruloids may now be considered. The most likely agent appears to be a gas, and the most readily available gas in a rhyolite lava is steam. That a cooling acid lava with locally high water content could produce the necessary pressure, is shown by the work of Morey (1922, 1924) who has made a special study of the development of pressure in magmas as a result of crystallization (see also Niggli, 1929, p. 2).

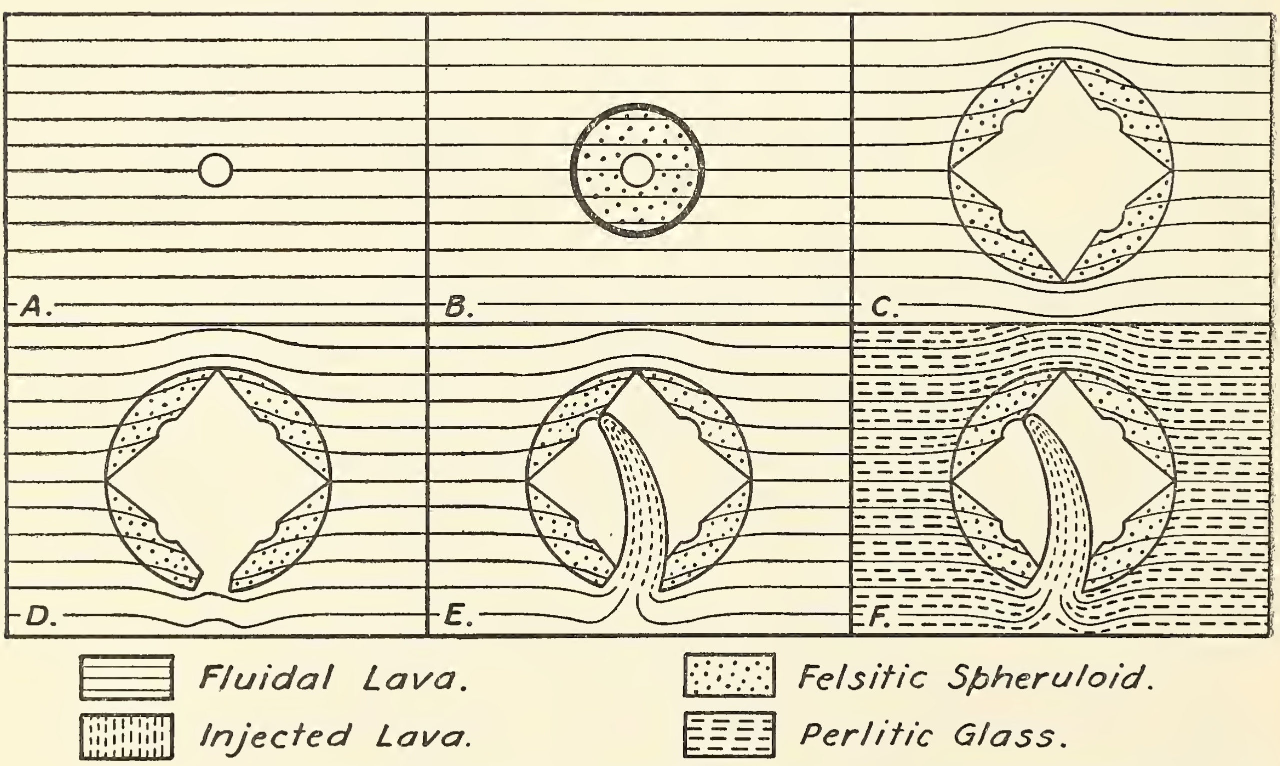
Morey (1924, p. 292) explains that in systems in which volatile and non-volatile components are both present "we have the unusual condition that the vapour pressure of the system does not decrease with decreasing temperature, as is almost the universal rule, but on the contrary increases as the temperature falls." More particularly, and bearing even more closely on our problem, Morey adds that "In a laboratory study of mixtures of orthoclase, quartz and water we have been able to obtain liquid solutions at 600° and a water vapour pressure of approximately 700 atmospheres . . . ." It would seem from these statements that in 'wet' rhyolitic lavas there exists in potential form the agent necessary for the internal compression that produces hollow spheruloids.

The fact that solid spheruloids are sometimes found in close proximity to hollow spheruloids suggests that the distribution of water in the parent lava was irregular and sporadic. Such a condition of affairs is probable enough in view of the work carried out by Shepherd (1938, p. 338) who, as a result of his experiences, states that "The distribution of the volatiles in rocks and lavas is largely fortuitous." In particular, and after sampling and analysing many rhyolitic glasses, he concluded that "water is not uniformly distributed through any given field exposure."

(G) Interpretation of Development.

A study of the spheruloids of Binna Burra in the field, combined with microscopical examination in the laboratory, enables one to determine with tolerable certainty, the succession of events in the development of these objects, even if the processes controlling some of those events are not clearly understood. No one specimen has been discovered that, in itself, provides material evidence on which to base a complete history (although one particular hollow spheruloid is remarkably illuminating), but many specimens show the sequence clearly for two or more successive steps. In this way certain short sequences can be established based on the mutually confirmatory evidence of several different spheruloids. Further progress is possible owing to the overlapping of the evidence derived from distinct specimens. By the combination of such overlapping sequences many of the numerous events indicated by solid or by hollow spheruloids may be confidently arranged in simple sequence.

But even after full use has been made of this method there are certain events which, while precisely placed in their own restricted series, do not fall automatically into place in any general sequence. These points are illustrated by the accompanying table in which the sequence of events within any particular vertical column is well established. It will be noted that the several different sequences are based on spheruloids of different types and the question arises: To what extent is it legitimate to draw up one general, composite sequence by dovetailing the events shown in the separate sequences? On the one hand, all the spheruloids are strikingly similar in such essential features as lithology, and they are found almost side by side in a common environment. These facts would lead one to expect their individual histories to be closely similar. But, on the other hand, considerable variation exists even in what may well be important characters. For example, the containing crust is strikingly conspicuous in some specimens, is indistinct in others, and may be altogether lacking in still other specimens. The central vesicle, too, may or may not be present. The spheruloid may be solid or it may be hollow. The presence of such diversity suggests that the construction of a general sequence based on spheruloids of different types should be of a tentative nature only. In the table, such a provisional correlation has been attempted by spacing the events of each established sequence to allow



Text-fig. 3.—Diagram showing A, initial vesicle; B, mature spheruloid in its confining integument; C, distended spheruloid; D, ruptured spheruloid; E, lava ribbon injected; F, final consolidation. (See Plate XI., fig. 1.)

the interlocking of those of the other. Although all the evidence indicates that the development of spheruloids is a very rapid process as compared with the rate of solidification of the enclosing lava, nevertheless their history can be divided into several phases. (See Table II.)

1. The Preliminary Phase.—The first or preliminary phase in the evolution of the spheruloids includes all those events which these bodies experience in common with the lava from which they are presently to be differentiated. This phase appears to have been normal in all respects. At its close there existed a somewhat viscous acid lava with well developed fluxion phenomena and with phenocrysts of quartz, sanidine, oligoclase and biotite. The water content of the lava was notably high and appears to have been unevenly distributed and to have been concentrated particularly along certain flow planes.

2. The Initial Stage.—This phase began with the crystallization of the lava about certain points or about certain vesicles which in some cases were more or less restricted to certain flow planes, while in others they were sporadically distributed.

Table II.

Established Sequences.

From Microslides.	See Plate IX, Fig. 1.	See Plate X, Fig. 1.	See Plate XI Fig. 1.	Generalized Sequence.	
Phenocrysts formed .. Phenocrysts embayed .. Fluxion developed				Parent Lava of Preliminary Phase Spheruloids Groundmass	
Flow minerals formed ..	Spheruloid initiated	Central vesicle formed		Initial Phase	Increasing Viscosity ↓
Independent minerals formed	Spheruloid enlarged by coalescence	Spheruloid developed by growth as unit		Developmental Phase	
	Enclosing skin formed	Spheruloid complete		Mature Phase	
		Spheruloid distended	Spheruloid distended	Distended Phase	
			Spheruloid ruptured Lava ribbon injected Lava ribbon solidified	Supplementary Phase	
		Tridymite deposited in cavity	Tridymite deposited on ribbon	Final Phase of Spheruloids in Glass	

3. The Developmental Phase.—About these points crystallization began to develop. Probably the lava was still moving slowly, for the first minerals to be devoloped are orientated parallel to the flow planes. The area affected by crystallization spread out in the form of a progressively enlarging sphere, but the sphere was not at this stage contained by any integument nor as it grew did it interfere with the fluxion planes, with the orientation of phenocrysts, or with any other earlier structure. This spreading without interference, or

peaceful penetration, is a characteristic and essential feature in the growth of spheruloids. When two such growing spheres met they coalesced by simply merging into one another without leaving any trace of junction.

4. The Mature Phase.—There arrived a time when some, but not all, spheruloids developed a crust which effectively prevented further growth except by inflation. With the completion of the mature phase the spheruloids were firmly established as independent units and in their subsequent history acted as such.

5. The Distended Phase.—While some of the above individuals showed no further development or modification and ended as solid spheruloids, others which possessed a greater water content were considerably distended and made more perfectly spherical with a thinner integument as the falling temperature set free the steam and inflated them. The expansion may in many cases have been continuous, but in some it was clearly spasmodic.

6. The Supplementary Phase.—One large spheruloid shows that after its solidification and distension the surrounding lava was still fluid and that the external pressure of the lava was greater than the internal compression at this stage. As a consequence, highly viscous lava was forced into the hollow spheruloid through cracks which it enlarged in the process.

7. The Final Phase.—Finally tridymite was deposited on the surfaces of cavities and cracks within the spheruloids, as the spheruloids themselves became sealed within the solidified glassy lava.

SUMMARY.

This paper considers the nature, origin and growth of certain bodies found within rhyolites and rhyolitic glasses which, while similar in many respects to spherulites, differ from them in the lack of any suggestion of radial crystallization. For these the name "Spheruloids" has been proposed.

ACKNOWLEDGMENT.

The late Mr. Arthur Groom of Binna Burra gave generous assistance and guidance in the field and provided the excellent photographs in Plates VIII. and XI.

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EXPLANATION OF PLATES.

Plate VIII.

Large spheruloids at Binna Burra showing secondary growths in Figure 1 and distension due to internal compression in Figure 3.

Plate IX.

Smaller spheruloids, approximately natural size.

Figure 1.—Mature undistended spheruloid with thick integument.

Figure 2.—Hemi-spheruloids developed on one side of fluxion plane.

Figure 3.—Continuity of fluxion planes through spheruloids.

Plate X.

Distended spheruloids, approximately natural size.

Figure 1.—Central vesicle and broken segments of a thin-skinned spheruloid embedded in perlitic glass. (The analyses on p. 59 were made from similar material nearby.)

Figure 2.—A segment of a distended spheruloid showing radial fracture pattern and concentric terraces due to spasmodic rupture.

Figure 3.—Radial fracture pattern in flattened segment of a distended spheruloid. The fractured surface is covered with plates of tridymite.

Plate XI.

Figure 1.—Viscous lava injected from below into solid but distended spheruloid. The lava has sagged under its own weight. One-fifth natural size.

Figure 2.—Pattern imposed on lava as it was forced through a gradually expanding fracture. The lava ribbon was subsequently covered by crystals of tridymite. Two-thirds natural size.


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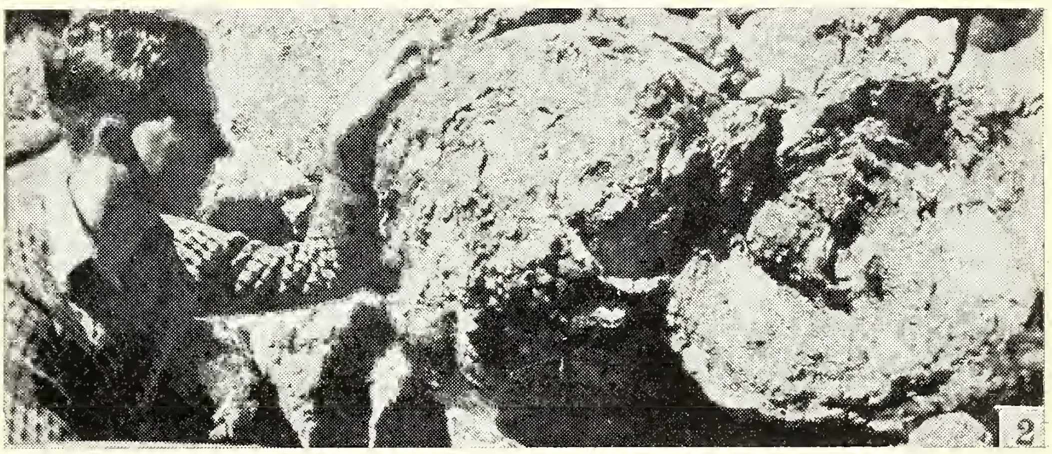
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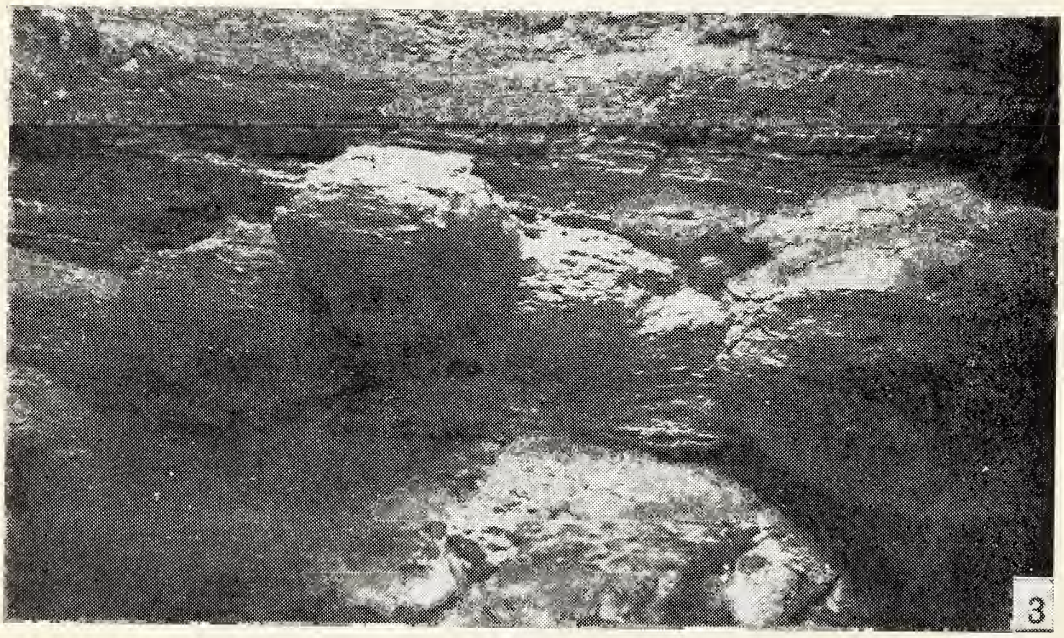

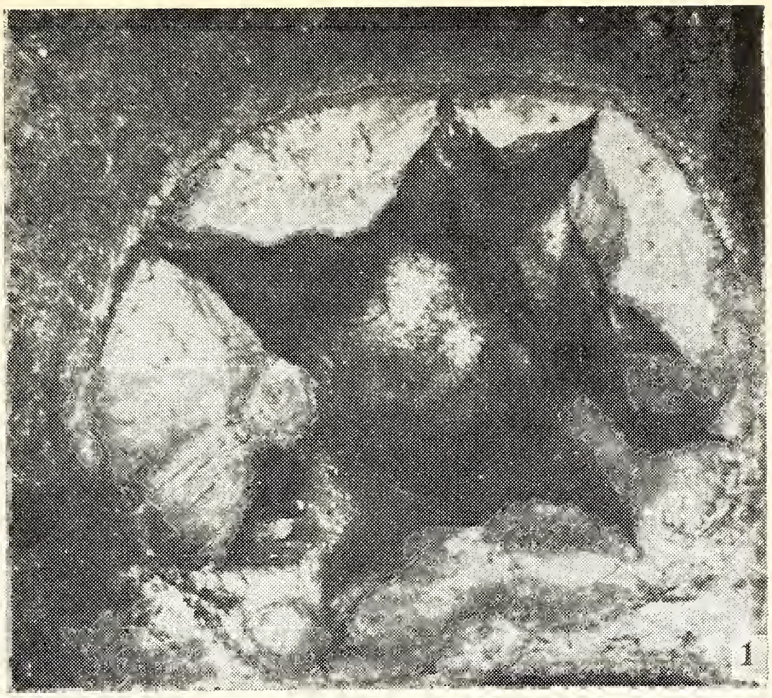
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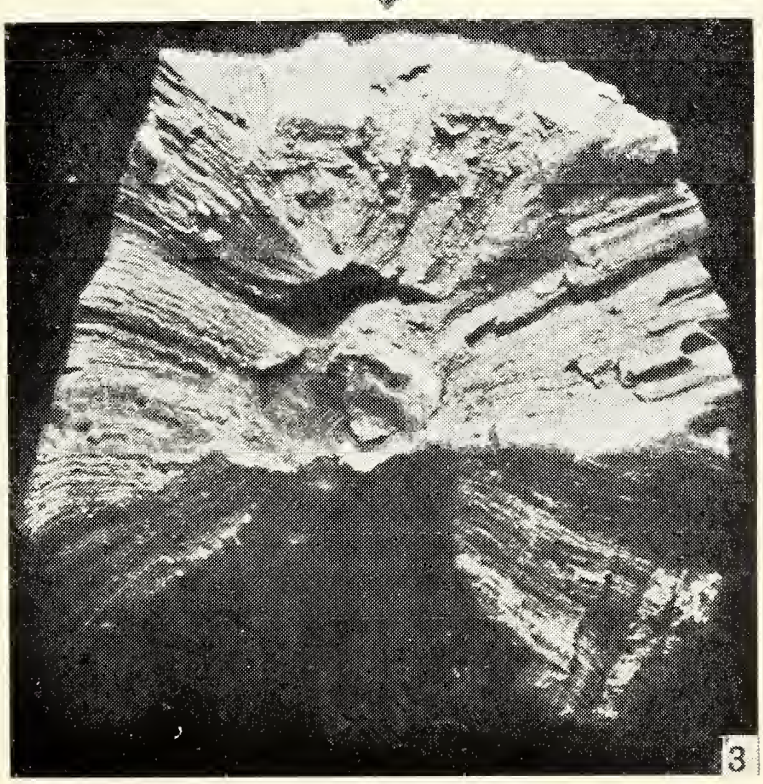
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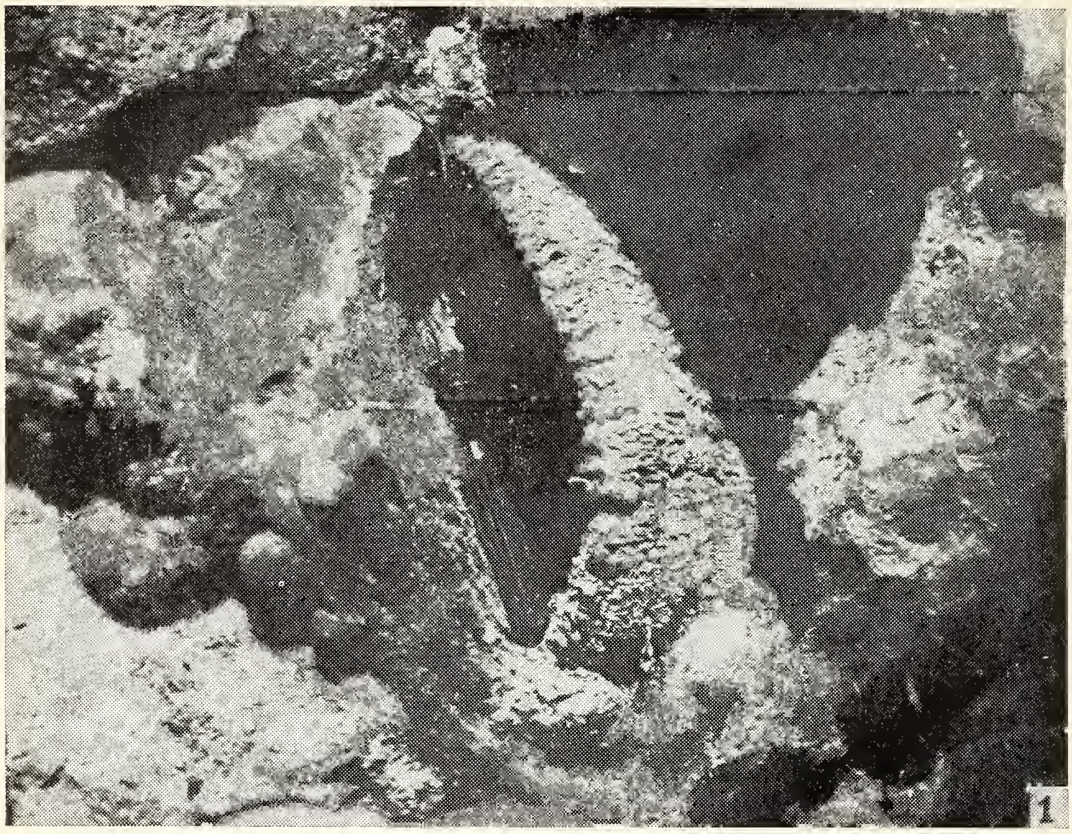

Vol. LXV., No. 4.

PRONOUNCED PARAMERAL DIFFERENTIATION IN THE WOMBAT (LASIORHINUS).

By Richard Tucker, The Veterinary School, University of Queensland.

(With Plate XII.)

(*Received* 13*th April*, 1953; *issued separately* 13*th September*, 1954.)

The theoretical and operational value of some morphological concepts is generally recognised. Homology, analogy, correlation and symmetry as well as other structural relations are often used as a lead for investigations and as an instrument of description.

Among the most useful concepts is that of paramery. It originates from the geometrical, now rather historical, trend in morphology, and its context resembles the concepts of isotopes in chemistry. The problem of morpho-functional differentiation in antimers may be of interest to every morphologist and zoologist who is busy with the problems of bilateral symmetry, paramery and teratology as well as with the plasticity of animal structures and adaptative phenomena.

Great parameral differentiations are occasionally reported. Colyer (1936) described the skulls of *Panthera tigris, Cercopithecus aethiops johnstoni, Papio hamandryas, Lagotrix infumatus* and *Equus caballus.* The same author (1951) reported the skull of *Macaca sinica.* The conclusions reached by him are of a functional character, for he has drawn attention to a "wonderful plasticity of the bones during their growing period." He has nevertheless been forced to stress that in the majority of phenomena of asymmetry of the skull "the cause is hidden in obscurity."

The specimen to be described is the skull of a Wombat (*Lasiorhinus latifrons barnardi*) from Epping Forest Station, north-west of Clermont, Queensland, preserved in the Queensland Museum (No. 6283). The whole skull, the asymmetry of which was briefly commented upon by Longman (1939), is twisted in both sagittal and transversal planes (fig. 1, fig. 2 and fig. 3). It differs from Colyer's skulls in that the changes overlapped the splanchnocranium as well as the neurocranium.

The main parameral differences are as follows:—

	Left Paramer.	Right Paramer.
1.	The small incisor (fig. 1).	The large incisor (fig. 1).
2.	The intermaxillo-maxillar suture curved strongly (fig. 4).	The intermaxillo-maxillar suture curved slightly (fig. 5).
3.	The infraorbital foramen directed laterally (fig. 4).	The infraorbital foramen directed anteriorly (fig. 5).
4.	The maxillar crista situated caudally from the infraorbital foramen (fig. 4).	The maxillar crista situated laterally from the infraorbital foramen (fig. 5).

5. Short frontal process of the maxillary bone (fig. 4).	Long frontal process of the maxillary bone (fig. 5).
6. The facial lamina of the lacrimal bone broad (fig. 4).	The facial lamina of the lacrimal bone narrower (fig. 5).
7. Prelacrimal part of the zygomatic bone narrow (fig. 4).	Prelacrimal part of the zygomatic bone broad (fig. 5).
8. The orbita high and round (fig. 4).	The orbita low and elongated (fig. 5).
9. The zygomatic bone short (fig. 4).	The zygomatic bone long (fig. 5).
10. Developed synostosis between zygomatic and temporal bones (figs. 4 and 6).	Loose connections between zygomatic and temporal bones (figs. 5 and 2).
11. The temporal fossa wide (figs. 1 and 3).	The temporal fossa narrow (figs. 1 and 3).
12. In the temporal fossa six foramina (figs. 1 and 3).	In the temporal fossa four foramina (figs. 1 and 3).
13. The postero-temporal fossa elongated ventro-dorsally (fig. 6).	The postero-temporal fossa elongated postero-anteriorly (fig. 7).
14. The foramen of the hypoglossal nerve large (fig. 8).	The foramen of the hypoglossal nerve small (figs. 8 and 2).
15. One accessory foramen of the hypoglossal nerve (figs. 8 and 2).	Two accessory foramina of the hypoglossal nerve (figs. 8 and 2).
16. The buccal fossa deep (figs. 8 and 2).	The buccal fossa shallow (figs. 8 and 2).
17. The palatine process of the maxillary bone narrow (figs. 8 and 2).	The palatine process of the maxillary bone wide (figs. 8 and 2).
18. High crown of the teeth (fig. 2).	Low crown of the teeth (fig. 2).
19. The outline of the zygomatic arch elongated transversally (figs. 8, 1, 2 and 3).	The outline of the zygomatic arch elongated anteriorly (figs. 8, 1, 2 and 3).
20. On the ventral face of the zygomatic arch no fissure between zygomatic and temporal bones (fig. 8).	On the ventral face of the zygomatic arch a deep fissure between zygomatic and temporal bones (fig. 8).

On the level of the parieto-frontal suture there is present a deep semicircular groove (figs. 1 and 3).

The peculiarities in the composition of the mandible are also great. The whole structure is bent to the left (figs. 9 and 10). The dental roots are exposed symmetrically, but on the left side to a higher degree (fig. 9). The main differences are:—

Left Paramer of Mandible.	Right Paramer of Mandible.
1. Short mandibular ramus (figs. 9 and 10).	Long mandibular ramus (figs. 9 and 10).
2. The last teeth are lower than the rest (figs. 10 and 11).	The crowns of the teeth are on the same level (figs. 10 and 11).
3. The incisor is well developed (figs. 10 and 11).	The incisor is poorly developed (figs. 10 and 11).
4. The alveolar process is short (figs. 10 and 11).	The alveolar process is long (figs. 10 and 11).
5. The teeth reach the caudal end of the alveolar process (figs. 10 and 11).	The teeth do not reach the caudal end of the alveolar process (figs. 10 and 11).
6. The mandibular foramen undivided, surrounded by a deep fossa (figs. 10 and 12).	The mandibular foramen divided by the median tubercle. The surrounding fossa is shallow (figs. 10 and 12).
7. Mandibular notch narrow and deep (fig. 11).	Mandibular notch wide and open (fig. 13).
8. Lateral mandibular foramen very large, surrounded by a deep fossa (fig. 11).	Lateral mandibular foramen small, surrounded by a shallow fossa (fig. 13).
9. Two laterally situated mental foramina (fig. 11).	Four laterally situated mental foramina (fig. 13).

DISCUSSION.

In the described skull there is no sign of a major dental abnormality, and the asymmetries extend throughout the skull. In these points the skull differs from the majority of Colyer's descriptions. The pain or teratomorphic dental formation, which, he claims, forms the primary cause of functional abnormality, does not appear in this case. In addition, many details which result from the differential analysis of paramers could not be explained by a simple functional deviation. The differentiated structure of mental and hypoglossal foramina, size and shape of mandibular foramina, the number of foramina in the temporal fossa, formation of synostoses, morphology of buccal fossa and many other features are examples of these. The morphology of both paramers differs to such an extent that if seen separately, there is little doubt that they would be considered as parts of two different skulls. Neither could the embryonal parameral asymmetry of gradients suggested by Child (1941) explain the described phenomena.

The causative factors may be due to one or a combination of the following characters:—functional, correlational, developmental, and genetical.

Accordingly, the phenomenon may be investigated for—

(*a*) Distribution of genetical material in paramers (genetical differences of paramers especially in heterozygotes, or genetical compositions of paramers). It is, however, difficult to find references for genetical parameral distribution except the data on regulative and mosaic eggs and the theory of gradients (Child 1941).

(*b*) Genotype-phenotype relations with the study of organismic plasticity and environment. These useful general concepts are still lacking in operational precision which is so important in investigations.

(*c*) Intraorganismic relations. An attempt is made elsewhere by the author to find the operational possibilities in this line.

SUMMARY.

The pronounced parameral differentiations in the skull of a wombat (*Lasiorhinus*) are described in detail. The literature and problems of this phenomenon are shortly discussed.

ACKNOWLEDGMENTS.

I wish to express my thanks to Professor T. K. Ewer for his interest and kindness in reading this manuscript, also to Mr. G. Mack, Director of the Queensland Museum for useful suggestions and to him and his staff for facilities made available to me during this investigation.

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EXPLANATION OF PLATE XII.

Figure 1.—a. Incisors; b. Temporal fossae; c. Temporal foramina; d. Zygomatic arch; e. Semicircular groove.

Figure 2.—a. Junction between zygomatic and temporal bones; b. Hypoglossal foramina; c. Palatine process; d. Zygomatic arch.

Figure 3.—a. Temporal fossae; b. Temporal foramina; c. Zygomatic arch; d. Semicircular groove.

Figure 4.—The left paramer. a. Intermaxillo-maxillar suture; b. Infraorbital foramen; c. Maxillar crista; d. Frontal process of maxillary bone; e. Prelacrimal part of zygomatic bone; f. Orbit; g. Zygomatic bone; h. Temporal bone.

Figure 5.—The right paramer. a. Intermaxillo-maxillar suture; b. Infraorbital foramen; c. Maxillar crista; d. Frontal process of maxillary bone; e. Prelacrimal part of zygomatic bone; f. Orbit; g. Zygomatic bone; h. Temporal bone.

Figure 6.—Left paramer. a. Zygomatic bone; b. Temporal bone; c. Postero-temporal fossa.

Figure 7.—Right paramer. a. Postero-temporal fossa; b. Temporal bone; c. Temporal fossa.

Figure 8.—a. Hypoglossal foramina; b. Palatine process; c. Zygomatic arch; d. Temporal bone.

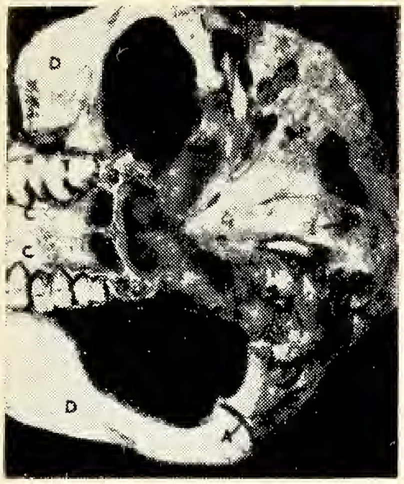
Figure 9.—The mandibular ramus and exposure of dental roots.

Figure 10.—a. Alveolar processes; b. Incisors; c. Mandibular foramen.

Figure 11.—a. Alveolar processes; b. Incisors; c. Lateral mandibular fossa and foramen; d. Mandibular foramen; e. Mandibular notch.

Figure 12.—Mandibular foramen.

Figure 13.—Righ paramer. a. Lateral mandibular fossa and foramina; b. Mandibular notch.



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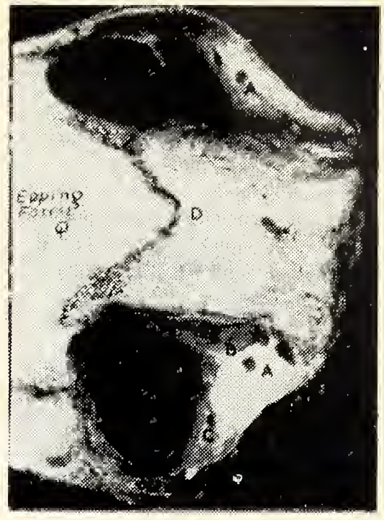

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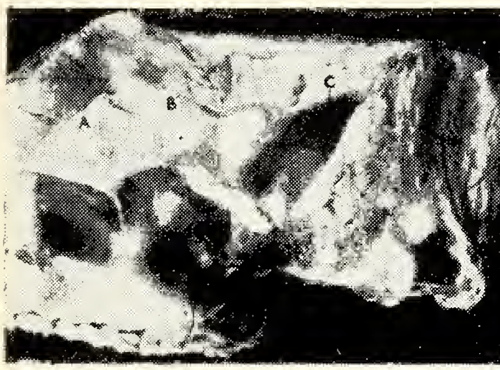

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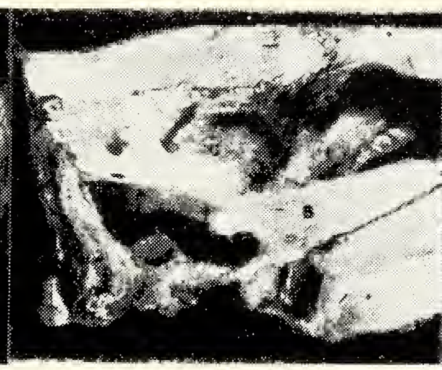

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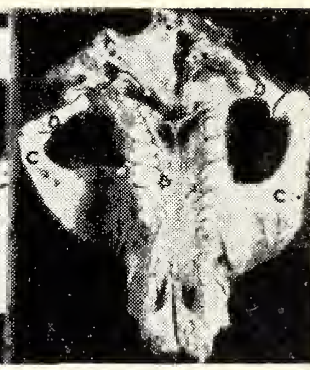

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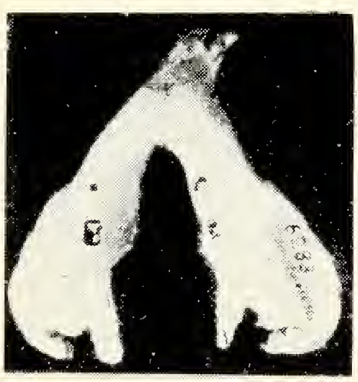

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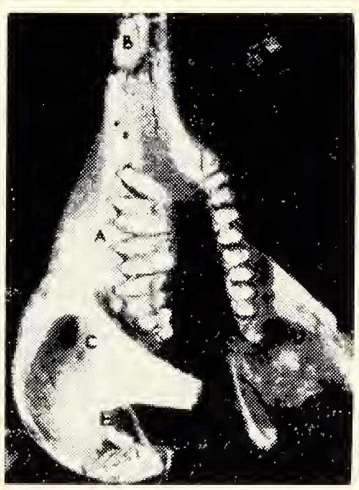

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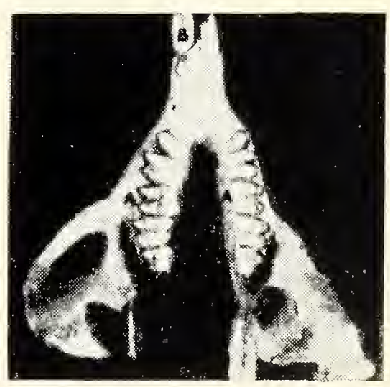

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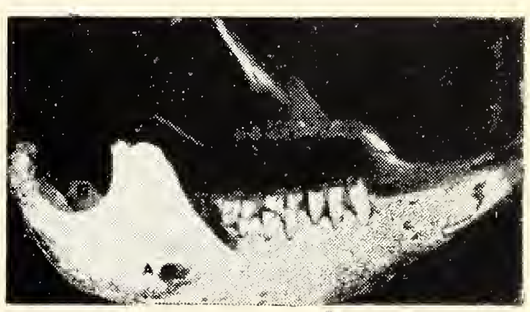

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The Royal Society of Queensland.

Report of the Council for 1952.

To the Members of the Royal Society of Queensland.

Your Council has pleasure in submitting the Annual Report of the Society for 1952.

The meeting place was changed to the lecture theatre of the Physiology Department of the University, William street, and the thanks of the Society are due to Associate Professor H. J. G. Hines, acting head of the Department during that period, and his staff for their co-operation and hospitality.

Ten meetings were held during the year, including two special meetings. Six addresses were given and two evenings were devoted to papers and exhibits. On behalf of the Council of A.N.Z.A.A.S., the 1952 Mueller Medal for Natural Science was presented to Mr. Heber A. Longman.

A special meeting was called to consider a revision of the Rules of the Society which had been prepared by the Council. The Council also revised the instructions to authors contributing to the Proceedings of the Society.

Dr. I. M. Mackerras and Miss K. Robinson were appointed as delegates for the Society to the Council of A.N.Z.A.A.S.

Several original papers were accepted for publication in the Proceedings. During the year Volume LXII. (1950) was issued, and at present Volume LXIII. (1951) is in the hands of the printer. In an effort to speed up publication, manuscripts on acceptance are passed to the printer for publication, being issued separately well ahead of the complete volume.

During the year there were 1,398 additions to the Library and five new exchanges were established. The cataloguing is proceeding. It is anticipated that the new quarters of the Library in the Administration block of the University, George street, should be occupied by the end of March, 1953.

There are now 6 honorary life members, 9 life members, 1 corresponding member, 217 ordinary members and 10 associate members of the Society. During the year the Society lost 1 member by death and 7 by resignation; the names of 12 members were removed for arrears; 10 ordinary members and 5 associate members were elected.

Attendance at Council Meetings was as follows:—I. M. Mackerras, 8; H. J. G. Hines, 6; S. T. Blake, 8; D. F. Sandars, 8; K. Robinson, 7; E. N. Marks, 5; F. S. Colliver, 7; G. Mack, 7; W. Stephenson, 6; J. H. Simmonds, 6; M. Shaw, 3; L. J. H. Teakle, 1.

I. M. MACKERRAS, President.

DOROTHEA F. SANDARS, Hon. Secretary.

KATHLEEN ROBINSON, Asst. Hon. Secretary.

THE ROYAL SOCIETY OF QUEENSLAND.

STATEMENT OF RECEIPTS AND EXPENDITURE FOR YEAR ENDED 31st DECEMBER, 1952.

Receipts.

	£ s. d.	£ s. d.
Balance in Commonwealth Bank 31/12/51	563 6 8	
Cash in Hand 31/12/51	17 5 4	
		580 12 0
Subscriptions—		
1952 Membership	206 11 6	
Arrears	66 18 6	
Life	15 15 0	
		289 5 0
Commonwealth Loan Interest	10 0 0	
Commonwealth Savings Bank Interest ..	10 14 2	
		20 14 2
Donation	..	0 6 0
Sale of Reprints and Society Proceedings	..	106 8 3
Exchange	..	1 2 9
		£998 8 2

Expenditure.

	£ s. d.	£ s. d.	£ s. d.
Watson Ferguson & Co.—Remaking Process Blocks for Vol. LXI. (1949) ..		..	27 11 0
Government Printer — Part Payment Vol. LXII. (1950)		..	300 0 0
Library Insurance		..	1 18 5
Purchase, Royal Society Proceedings B., Missing Parts		..	1 16 0
Stationery, Stamps, &c.—			
Secretary		25 13 11	
Treasurer		0 17 0	
Librarian		17 2 11½	
			43 13 10½
Supper—			
Refreshments	12 10 11		
Utensils	2 12 1		
		15 3 0	
Less Collections—March-June		2 11 0	
			12 12 0
Printing, &c.—			
Envelopes		6 19 2	
Foolscap and Stencils		9 8 4	
			16 7 6
Donation (1951 — Australian National Committee of Radio Science ..		..	10 0 0
Balance in Commonwealth Bank 31/12/52		..	575 4 10
Cash in Hand 31/12/52—			
Secretary		4 18 4½	
Treasurer		1 12 10½	
Librarian		2 13 3½	
			9 4 6½
			£998 8 2

The total amount due to Government Printer for Vol. LXII. is £611 5s.; payment of balance awaits advice of amount of Government Subsidy. In addition to the Credit Balance shown in the above statement, the Society holds the following Capital Funds—

Commonwealth Loan	£320
Savings Certificates	2
	£322

held in safe custody by the Commonwealth Bank of Australia, Adelaide street, Brisbane.

Examined and found correct.

[Signed] L. P. HERDSMAN, Hon. Auditor.
9th March, 1953.

[Signed] ELIZABETH N. MARKS, Hon. Treasurer.
27th February, 1953.

Abstract of Proceedings, 30th March, 1953.

The Annual General Meeting of the Society was held in the Physiology Department of the University of Queensland on Monday, 30th March. The President, Dr. I. M. Mackerras, was in the chair. The minutes of the last Annual Meeting were confirmed. The Annual Report was adopted and the Balance-sheet received.

The following members were elected as Office Bearers for 1953:—

President: S. T. Blake.

Vice-President: M. Shaw.

Hon. Secretary: D. F. Sandars.

Asst. Hon. Secretary: K. Robinson.

Hon. Treasurer: E. N. Marks.

Hon. Librarian: F. S. Colliver.

Hon. Editor: G. Mack.

Councillors: B. Howard, A. R. Brimblecombe, T. K. Ewer, F. T. M. White, G. L. Wilson.

Hon. Auditor: L. P. Herdsman.

The Presidential Address, entitled "Animal Reservoirs of Infection in Australia," was delivered by Dr. I. M. Mackerras.

Abstract of Proceedings, 27th April, 1953.

The Ordinary Monthly Meeting of the Society was held in the Physiology Department of the University of Queensland on Monday, 27th April. The President, Mr. S. T. Blake, was in the chair. Thirty-eight members and friends were present. The minutes of the previous Ordinary Meeting were confirmed. Mr. I. R. McLeod was nominated for Ordinary Membership.

Professor T. Kelley delivered an address entitled "Conservation." He spoke of the need for the co-ordination of research, education and work on the land for the maintenance of renewable resources and conservation of those which were unrenewable. Young countries tended not to worry about resources until they had attained cultural maturity. The type of soil together with the high rainfall and the prevailing winds have led to soil erosion in parts of Australia, especially in the wheat belt of the east coast. Wind erosion has occurred in Victoria, South Australia, and Western Australia and in New South Wales alone, 1,000,000 acres are out of production.

In the United States of America, many attempts at conservation have been made; river basins are controlled; land is classified according to its capabilities and the system of rural zonation ensures most efficient production for a particular area; forest commissioners supervise forest conservation; and with respect to taxation, land value is assessed on the basis of land capability. It was suggested that similar methods could be instituted in Queensland and research could be undertaken into greater utilisation of food from the ocean.

Abstract of Proceedings, 25th May, 1953.

The Ordinary Monthly Meeting of the Society was held in the Physiology Department of the University of Queensland on Monday, 25th May, 1953. The President, Mr. S. T. Blake, was in the chair. Fifteen members and friends were present. Mr. I. R. McLeod was elected to Ordinary Membership.

Mr. S. T. Blake exhibited several books showing methods used in botanical illustrations. The copper plates in Dampier's "A Voyage to New Holland . . ." (1703) were the first illustrations of Australian plants. Printed figures coloured by hand were exemplified in "Rumphia," "Flora Antarctica" and the greater part of the "Botanical Magazine." Colour-printing has been used in recent volumes of the last mentioned.

Mr. F. S. Colliver exhibited (*a*) an artifact, a well-formed chopper, found in the same terrace as, but further up stream from, the site of the Keilor skull; (*b*) Wire Copper, a tightly packed mass of crystalline copper in wire form; (*c*) Fulgurites in sand from Moreton Island apparently formed by lightning, and in basaltic soil from Burnett Heads' Road, Bundaberg, apparently formed by the breaking of a high tension wire.

Mr. L. C. Ball exhibited (*a*) a rock specimen from a ridge near the Waterford Bridge, consisting of fine-grained, chalcedonic silica, and assumed to be a complete replacement of greywacke or phyllite. The most arresting feature of the specimen was its lamellar pseudo-organic structure, foreign to normal Brisbane schist. Shearing has been suggested as the cause, but the explanation was not altogether satisfactory; (*b*) daily weather charts of Australia in April, 1953, which have been used as a basis for research, in an endeavour to determine an analogy between the meteorologists' mobile cold fronts and the geologists' fixed crustal fissures, respectively atmospheric and lithospheric.

Mr. H. J. T. Bake tabled a copy of an Admiralty Notice to Mariners and pointed out that echo depth soundings can be in error owing to scale repetition. He pointed out that the Admiralty advises that, where unexpected shoal soundings are observed, a cast should be taken with a lead-line to verify the echo sounding readings.

Abstract of Proceedings, 29th June, 1953.

The Ordinary Monthly Meeting of the Society was held in the Physiology Department of the University of Queensland on Monday, 29th June. The President, Mr. S. T. Blake, was in the chair. Thirty-eight members and friends were present. The President asked members to stand in remembrance of both the late Dr. R. Hamlyn-Harris, a past President of the Society, and the late Mr. L. Hitchcock, a past Editor and Librarian of the Society. The minutes of the previous meeting were read, amended and confirmed. Mr. R. T. Mathews was elected to Ordinary Membership. The Librarian reported that there had been 416 additions to the library.

An address on "The Fitzroy River Model" was given by Professor Shaw, Mr. Hinckley and Dr. McKay.

Professor Shaw discussed the need for a new port for Rockhampton, to replace Port Alma, and how it was proposed to see if a self-scouring channel could be produced by making tests on a large model. He showed, by using simple models, how tidal movements could be synthesised by the combination of simple harmonic motions. The tide synthesiser designed and made in the Engineering School was described and the simple constantly driven pump and its control valve were explained.

Mr. Hinckley explained the electronic control used to produce tides in the model by automatically setting the valve position to regulate the pump discharge to give the desired rate of rise or fall of the tide as determined by the output of the synthesiser. As a random drift of mean sea level could still occur the difference between the actual and the desired level of the water surface was measured continuously and the valve opening adjusted to minimise any error detected. Results showed that the tide wave produced at the control point approximated very closely to that desired.

Dr. McKay, who dealt with civil engineering problems associated with such investigations, pointed out that hydraulic scale models were not exact miniatures. Unfortunately the forces present did not change in the same proportion with diminishing size. Gravitational forces predominated in a model of this type and formed the basis of the design but modifications were necessary for experimental expediency—the vertical scale was distorted to give greater tractive force to move sand on the model, and to account for non-scalar changes in other forces—viscous surface tension, &c. The parts played by viscosity, &c., were not definitely known and it was necessary to "prove" the model by making it reproduce known natural phenomena, before proceeding to predict changes which might occur or could be induced. It has been found necessary to use a fluid more viscous than water for the tide to be distributed with equal accuracy throughout the estuary. The production of 3,000 gallons of a cheap viscous fluid proved very difficult and was solved ultimately by using clay solution. It remained to check the sand movement with the known history of the estuary before starting improvement experiments.

Abstract of Proceedings, 27th July, 1953.

The Ordinary Monthly Meeting of the Society was held in the Physiology Department of the University of Queensland on Monday, 27th July. The President, Mr. S. T. Blake was in the chair. Twenty-nine members and friends were present. The minutes of the previous meeting were confirmed. Mr. E. H. Gurney was elected as an Honorary Life Member of the Society. The following were nominated for Ordinary Membership:—Miss B. Hoyling, Miss G. Dementjew, Miss P. L'Estrange, Mr. D. Bevan, Professor F. J. Schonell, Mr. B. R. Champ, Mr. R. L. Johnson. The Librarian reported that there had been 355 additions to the library.

Mr. S. T. Blake exhibited a small, rare orchid *Corbas undulatus* found at Coolum.

An address entitled "Overseas Medical and Biological Institutions" was delivered by Professor W. V. Macfarlane. He outlined briefly the activities of these institutions he had recently seen in the United States, and commented on departmental administration, outstanding personalities, apparatus used and university and laboratory architecture.

He stressed the advantage both to the staff and students of limiting the number of students handled by each staff member. This often necessitated student selection which greatly improved the quality of the work produced. The tremendous capacity for work of American research workers was an outstanding feature, as well as the extraordinary amount of money invested in the projects.

Abstract of Proceedings, 31st August, 1953.

The Ordinary Monthly Meeting of the Society was held in the Physiology Department of the University of Queensland on Monday, 31st August. The President, Mr. S. T. Blake was in the chair. Thirty-two members and friends were present. The minutes of the previous meeting were confirmed. The following were elected to Ordinary Membership:—Professor F. J. Schonell, Miss B. Hoyling, Mr. B. R. Champ, Miss G. Dementjew, Miss P. L'Estrange, Mr. D. Bevan, Mr. R. W. Johnson. The librarian reported that there had been 302 additions to the library.

An address, entitled "The Scientist and World Politics" was given by Professor N. Pfeffer. He said that, while the relation of science to world politics has been dramatized by the use of atomic weapons, there has always been a direct relation between the nature of war and the state of technology. However, war is now not only a conflict between nations in which both sides are really losers, but one in which the continued existence of civilised societies is at issue. There is a race between destructive potentialities of scientific discoveries applied to weapons and mankind's ability to make comparable progress in the social sciences and the humanities towards finding a method of regulating the relations of nations so that war can be prevented.

Immediately after the last war there arose a movement, not least among scientists, for world government. Yet it was too simple a solution. The call of national kind is still too strong; human attitudes cannot be changed at will or command or on rational demonstration, and for the present world government must remain a counsel of perfection.

In order to prevent war, the conduct of states in their relationships with each other must be subjected to the same kind of jurisdiction as has always been imposed on the conduct of individuals. This means an accepted code of conduct, an organism for adjudication and an organism for enforcing judgment. This was already conceived at the end of the first world war and given form in the League of Nations. The League failed, but it is clear that there has been a change since then, and behind the formation of the United Nations there was good faith. Men's attitude towards war has changed; even those of evil intentions must at least pretend to want peace. In this alone there is progress, even if the positive accomplishments of the United Nations are not substantial and cannot be until the mutual hostilities of the Western bloc and Russia are assuaged. Meanwhile the task of the scientist is no different from that of other men. It is doubtful, too, whether much of scientific method as it is understood by physical scientists is transferable to the social sciences: much of the current pseudo-scientific method now being applied in those fields is futile and sometimes spurious. Advance in social studies must be at least comparable to that in the physical sciences.

Abstract of Proceedings, 28th September, 1953.

The Ordinary Monthly Meeting of the Society was held in the Physiology Department of the University of Queensland on Monday, 28th September. The President, Mr. S. T. Blake, was in the chair. About thirty-six members and friends were present. The minutes of the previous meeting were confirmed. Dr. S. Mariti was nominated for Ordinary Membership. The Librarian reported that there had been 354 additions to the Library.

An address, entitled "The Fiery Serpent," was given by Dr. J. F. A. Sprent. He said that one of the oldest known parasites of animals was the guinea worm. This strange parasitic worm which inflicted suffering and struck panic into the people of bygone ages, was used as an introduction to the problem of the evolution of the nematodes. Their evolutionary history was traced along three main lines of development: (1) from soil inhabiting, free-living species; (2) from nematodes parasitic in terrestrial arthropods; (3) from nematodes parasitic in aquatic arthropods. Examples were given of the life history of various nematodes, the object being to illustrate possible stages which may have occurred throughout the evolutionary history of this group.

Abstracts of Proceedings, 26th October, 1953.

The Ordinary Monthly Meeting of the Society was held in the Physiology Department of the University of Queensland on Monday, 26th October. The President, Mr. S. T. Blake, was in the chair. About thirty-three members and friends were present. The minutes of the previous meeting were confirmed. Dr. S. Mariti was elected to Ordinary Membership. The Librarian reported that there had been 180 additions to the Library.

The following papers were read:—

"Spherulites and Allied Structures—Part II.—The Spherulites of Binna Burra," by Professor W. H. Bryan.

"The Structural History of the Brisbane Metamorphics—Part II. —Geology of Brisbane," by Professor W. H. Bryan and Dr. O. A. Jones.

"Pronounced Parameral Differentiation in the Wombat *Lasiorhinus*," by Dr. R. Tucker.

Mr. K. J. Bullock demonstrated the strain gauge apparatus used in the Mechanical Engineering Department of the University for measuring the strains and hence the stresses and forces in the Department's new experimental sugar mill. The method of calibration was shown.

Professor M. Shaw explained and demonstrated the interferometer which has been constructed in the Mechanical Engineering Department by Mr. R. W. Axon. The interferometer will be used to measure slip gauges in terms of the four major waves of cadmium light, red, green, blue and violet, and will be installed in the new air-conditioned meterology room which is approaching completion.

Mr. J. E. O'Hagan exhibited a Photo-electric Scanner for Electrophoretic Analysis. A drop of protein solution is placed on a filter paper strip saturated with buffer solution and a current at several hundred volts passed through the paper for some hours. The paper is then dried and the separated proteins stained. The paper is rendered translucent with an oil of the same refractive index as cellulose, and placed between glass plates in front of a fine slit, which is illuminated with a strong light source, and which has behind it a photo. cell connected to a meter calibrated for optical density. As the protein "picture" is traversed in front of the slit, the readings are plotted and from the curves obtained the concentration of each component of the protein mixture can be calculated. It is intended to use the technique for the investigation of changes in the protein fractions of human serum.

Mr. P. J. Skerman showed a series of Kodachrome slides depicting recent advances in pasture establishment and management in Queensland, and large-scale mechanical methods of clearing gidyea scrub. Irrigated pastures established at the Bureau of Investigation Research Station at Gatton have been successfully taken to Theodore in the Dawson Valley, the Atherton Tableland and the Blackall districts. Positive mixtures consisting of tropical grasses and legumes have been developed at the Bureau of Tropical Agriculture at South Johnstone and are now being developed at Atchee Creek for bullock fattening and dairying.

Abstract of Proceedings, 30th November, 1953.

A Special Meeting of the Society was held in the Physiology Department of the University of Queensland on Monday, 30th November. The President, Mr. S. T. Blake, was in the chair. Twenty-three members and friends were present.

Three rules of the Society were altered to read as follows:—

Rule 4.—Life members are such ordinary members as have commuted the ordinary subscription on payment of twenty guineas.

Rule 11.—Each ordinary member shall pay an annual subscription of thirty shillings, of which five-sixths will be paid to the journal account, and each associate shall pay an annual subscription of fifteen shillings.

Rule 12.—Ordinary members may at any time commute the annual subscription on payment of twenty guineas.

The Ordinary Monthly Meeting of the Society was held in the Physiology Department of the University of Queensland on Monday, 30th November. The President, Mr. S. T. Blake, was in the chair. Twenty-five members and friends were present. The minutes of the previous meeting were confirmed. Dr. Shirley Crawford and Mr. K. MacDonald were proposed for Ordinary Membership. The Librarian reported that there had been 517 additions to the Library.

An address entitled "Protection of Electrical Plant against Lightning" was delivered by Professor S. A. Prentice. He dealt briefly with lightning as a physical phenomenon and described the action of direct strikes on the various elements of a transmission system. Factors which determine the magnitude of the resulting voltages and currents were also explained together with the protective measures adopted in practical installations. The address concluded with a description of research work on the protection of electrical plant against lightning now being carried out in the University of Queensland.

A. H. TUCKER, Government Printer, Brisbane.

GUIDE FOR THE PREPARATION OF SYNOPSES

1. PURPOSE.

It is desirable that each paper be accompanied by a synopsis preferably appearing at the beginning. This synopsis is not part of the paper; it is intended to convey briefly the content of the paper, to draw attention to all new information and to the main conclusions. It should be factual.

2. STYLE OF WRITING.

The synopsis should be written concisely and in normal rather than abbreviated English. It is preferable to use the third person. Where possible use standard rather than proprietary terms, and avoid unnecessary contracting.

It should be presumed that the reader has some knowledge of the subject but has not read the paper. The synopsis should therefore be intelligible in itself without reference to the paper, for example it should not cite sections or illustrations by their numerical references in the text.

3. CONTENT.

The title of the paper is usually read as part of the synopsis. The opening sentence should be framed accordingly and repetition of the title avoided. If the title is insufficiently comprehensive the opening should indicate the subjects covered. Usually the beginning of a synopsis should state the objective of the investigation.

It is sometimes valuable to indicate the treatment of the subject by such words as: brief, exhaustive, theoretical, etc.

The synopsis should indicate newly observed facts, conclusions of an experiment or argument and, if possible, the essential parts of any new theory, treatment, apparatus, technique, etc.

It should contain the names of any new compound, mineral, species, etc., and any new numerical data, such as physical constants; if this is not possible it should draw attention to them. It is important to refer to new items and observations, even though some are incidental to the main purpose of the paper; such information may otherwise be hidden though it is often very useful.

When giving experimental results the synopsis should indicate the methods used; for new methods the basic principle, range of operation and degree of accuracy should be given.

4. DETAIL OF LAYOUT.

It is impossible to recommend a standard length for a synopsis. It should, however, be concise and should not normally exceed 100 words.

If it is necessary to refer to earlier work in the summary, the reference should always be given in the same manner as in the text. Otherwise references should be left out.

When a synopsis is completed, the author is urged to revise it carefully, removing redundant words, clarifying obscurities and rectifying errors in copying from the paper. Particular attention should be paid by him to scientific and proper names, numerical data and chemical and mathematical formulae

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VOL. LXV.

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PROCEEDINGS

OF THE

ROYAL SOCIETY

OF

QUEENSLAND

FOR 1954

VOL. LXVI.

ISSUED 12th OCTOBER, 1955.

PRICE: TWENTY-FIVE SHILLINGS.

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The Royal Society of Queensland.

Patron:

His Excellency Lieut-General Sir JOHN D. LAVARACK, K.C.M.G., K.C.V.O., K.B.E., C.B., D.S.O., C. de G.

OFFICERS, 1954.

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NOTICE TO AUTHORS

1. Papers should be double-spaced typescript on one side of the paper with ample margins, and must be accompanied by an abstract of not more than one hundred words prepared according to directions given on the inside back cover.

2. Papers must be complete and in a form suitable for publication when communicated to the Society and should be as concise as possible. All calculations, figures, tables, names, quotations and references to literature should be carefully checked.

3. The use of italics in the text should be restricted to the names of genera and groups of lower rank, foreign words and titles of periodicals.

4. Except in taxonomic papers, all references should be listed at the end of each paper and arranged alphabetically under authors' names, *e.g.*

   Bagnold, R. A., 1937. The Transport of Sand by Wind. *Geogr. J.*, 89, 409–438.

   Kelley, T. L., 1923. Statistical Method. New York, Macmillan Company. XI+390 pp., 24 fig.

   The corresponding references in the text should take one of the following forms :—

   Bagnold (1937), (Bagnold, 1937), Bagnold (1937, p. . . .), or (Bagnold 1937, p. . . .).

   In taxonomic papers references may be inserted in the text in accordance with established usage. Titles of periodicals should be abbreviated in accordance with the World List of Scientific Periodicals.

5. The cost of author's corrections to proof above what the Council considers a reasonable amount, must be borne by the author.

6. Each author will be supplied with fifty separate copies of his paper. Additional copies may be obtained at approximately cost price and should be ordered when the galley proof is returned.

7. The size of the printed plate will not exceed 8 in. x 4½ in., and drawings should be to this size, or preferably a convenient small multiple thereof. The effect of the necessary reduction on lettering and fine detail should be borne in mind. Text-figures should be drawn for reduction to a width not exceeding 4 in.

8. Drawing in line should be executed in intensely black ink such as good Indian ink, on a smooth surface, preferably Bristol board. Excessively fine, scratchy, or faint lines are to be avoided. Tints or washes cannot be reproduced in line drawings, in which the maximum degree of contrast is necessary.

9. Drawings or photographs for reproduction in half-tone, should where possible, be grouped for reproduction on one plate. They should be done or mounted on a smooth surface, such as Bristol board, as the grain of most drawing papers become visible on reproduction. Single photographs should be sent flat and unmounted. All prints should be on a glossy bromide or gas-light paper.

Vol. LXVI., No 1.

PRESIDENTIAL ADDRESS

SOME PIONEERS IN PLANT EXPLORATION AND CLASSIFICATION

(With four Text-figures.)

By S. T. Blake, Botanic Museum and Herbarium, Botanic Gardens, Brisbane.

(*Delivered before the Royal Society of Queensland, 29th March,* 1954.)

It has been well said that "as long as plants are cultivated and it is necessary to speak of them and write of them, even so long will some form of classification and nomenclature be necessary" (Masters, quoted by Bailey, 1913).

My address to-night, which might equally well have been called "Miscellaneous thoughts on the evolution of the knowledge of plants", has been inspired by the realization that the years 1953-4 mark the 50th, 90th, 150th, 200th and 250th anniversary of events of special significance in the history of botany in general and the knowledge of Australian plants in particular. In 1703 two important works were published; one is the third volume of William Dampier's *A Voyage to New Holland, etc., in the year* 1699, in which appeared the first published descriptions and figures of Australian plants and animals; the other is the *Methodus Plantarum* of John Ray in which was proposed a system of classification of plants that greatly influenced succeeding workers in this field. May, 1753, the date of publication of *Species Plantarum* by Carolus Linnaeus, is accepted as the starting point of modern botanical nomenclature. In March, 1803, after his famous voyage of exploration with the *Investigator* along the southern, eastern and part of the northern shores of Australia, Matthew Flinders left the north-eastern coast of Arnhem Land for his return to Sydney via Timor; on board the *Investigator* was Robert Brown, the first man to describe Australian plants in detail and the nature of the vegetation as a whole, later regarded as one of the greatest botanists of all time. In 1863 the first volume of George Bentham's *Flora Australiensis* was published; and in 1903 appeared the first part of J. H. Maiden's *A Critical Revision of the Genus Eucalyptus.*

I intend firstly to discuss some of the circumstances surrounding the publication of *Species Plantarum* and its effects on botany, followed by some reflections on classification and nomenclature. Then I propose to give brief accounts of the work of Brown and Bentham and some of the plant collectors in Queensland whose collections directly or indirectly provided a considerable part of the material for *Flora Australiensis,* chiefly those whose localities have often been wrongly quoted or misunderstood. I have mapped their collecting places as completely as possible from their original labels and journals or such letters or references to letters as have been available to me.

SPECIES PLANTARUM

The year 1753 was a momentous year for modern botany. In May of that year was published the two volumes of *Species Plantarum* by the Swedish botanist Carl Linné, perhaps better known by his latinized name Carolus Linnaeus, in which an attempt was made to define all known species of plants under a new system of nomenclature; this work is accepted as the starting point of modern nomenclature. The general plan had been worked out by Linnaeus not later than 1733, when he was 26 years old and living in Holland, along with other parts of what he called *Fundamenta Botanica* (Svenson 1945, Uggla 1953), but the first evidence that he was actively engaged on the work was in a letter to his close friend Abraham Bäck (Baeck) in September 1746 in which he wrote "I am busy with *Species Plantarum* and labouring from early to late so I almost turn grey" (Uggla 1953). It was not easy going. In October, 1749, he wrote "I begin to dismiss *Species Plantarum* from my thoughts altogether. Since last year I have not had time to look at them... But must I work myself to death?... What do I earn with this? One does not become wise before the end..." Then in June 1751: "I am now writing my *Species*... If I am permitted to boast a little I believe that something like this had not existed in 1,000 years. If I am allowed to finish it, it will be good. If not, I should at least wish to have a few sheets printed in order that the world should see what *could have* been made" (Uggla 1953), and in June, 1752.... "I have finished my *Species*" (Bryk 1953). The first of the two parts was published about eleven months later.

CLASSIFICATION AND NOMENCLATURE

At this stage it is worth while to consider the way plants were named in the 16th, 17th and early 18th centuries. Classification was based chiefly on texture, form and uses. Names were in Latin—the common language of science at that period—in the form of a more or less lengthy descriptive phrase of which the first part referred to the genus. According to Bartlett (quoted by Turrill 1942), "the concept of the genus must be as old as folk science itself. Two processes must have been operative in ancient times just as they are to-day. (1) With enlarging experience, people make finer distinctions, and need different names for newly distinguished entities which had originally been called by the same original name. The original name becomes generic in its application; variously qualified, it provides the basis for specific names. Thus genera are set up by analysis. (2) As the language becomes cumbersomely rich in separate names for closely similar things, there is a tendency towards grouping or classification under the same names on the basis of newly perceived similarities. Thus genera are set up by synthesis"... "The tendency to group plants into named genera, so generally characteristic of human thought and language, reflects the fact that there are not enough different words in the living current vocabulary of any language to supply each closely similar plant with a basically distinctive name". The idea of the genus, as this category in classification is understood to-day, and the generic name, go back at least to the *Pinax* of Gaspard Bauhin (1623) and was well established by Tournefort (1694 and 1700) and John Ray (1703). The genus was symbolized by a single word (usually) and was treated as the fundamental unit of classification; species were subsidiary units and each was named and at the same time distinguished from all other species of the genus by placing after the generic name a series of descriptive words (*differentiae*). The *differentiae* constituted the specific name; the discovery of further species in the genus usually meant that some, at any rate, of the existing names had to be modified to exclude the new species. Occasionally the specific name might consist of a single word.

Two examples of such names taken from Dampier (1703) are:

(1) *Equisetum Novae Hollandiae frutescens foliis longissimis* (=*Equisetum* of New Holland shrubby with very long leaves—now known as *Casuarina equisetifolia,* or coastal she-oak).

(2) *Colutea Novae Hollandiae floribus amplis coccineis, umbellatim dispositis macula purpurea notatis* (=*Colutea* of New Holland with large scarlet flowers umbellately arranged and marked with a purple spot—now known as *Clianthus speciosus* or Sturt's desert pea).

In principle this form of nomenclature is not very different from that found in the popular names of plants or animals in many languages, and it probably developed side by side with language. I have just mentioned the popular names of Dampier's plants and we have others like blue gum, white gum, drooping white gum, narrow-leafed ironbark and silver-leaved ironbark. It was in *Species Plantarum* that the device of using a combination of two words to denote every plant species was consistently employed. This handy method of referring to any species by using a generic name followed by a single qualifying word (the "specific epithet" in modern terminology) soon became popular and rather quickly replaced earlier systems of nomenclature. Linnaeus himself treated this innovation as of less importance than his reformed "specific names". He wrote (1751) that "The specific name makes the plant recognizable at first glance, since it contains the differentia inscribed in the plant itself. The *character naturalis* of a species is the *Descriptio*; but the *character essentialis* is the *Differentia*. I was the first to base specific names on essentials; previously no differentiae of value had been set up...." and in the introduction to *Species Plantarum* (1753) he stated "To set up the essential characters for the specific name is not an easy task; for it requires an accurate knowledge of many species, a most attentive investigation of the parts, the selection of differentiae and finally the proper application of the art of terminology, in order that the briefest and most effective name may be arrived at " (Svenson 1945).

As mentioned previously, the use of a generic name followed by a qualifier (the "trivial name" of Linnaeus or "specific epithet" of modern terminology) to denote a species had actually appeared in works of the 17th century but only incidentally. A few years before *Species Plantarum* Linnaeus wrote "*Nomina trivialia* may be admitted after a fashion; they consist of a single word freely selected from any source" (Linnaeus 1751) and "I have arranged the plants of Flora Suecica....; and so that I could study them in brevity, I found it advantageous to add to the generic name a short and insufficient epithet, which is made clear by the Flora itself" (Linnaeus 1749). "And so that I could study them in brevity"!! Linnaeus was not slow in recognizing the practical advantage of the binary nomenclature and consistently employed it after the appearance of *Species Plantarum*; from his preface to that work it is evident that he expected other botanists to follow his example. This expectation was realized, partly because of the intrinsic merits of the method, partly because of the merits of *Species Plantarum* as a whole. There was, of course, opposition. Many people complained that Linnaeus "changed the names" of a large number of plants. It took time for people, especially the older botanists, to get accustomed to the new system. Haller (1768) wrote "I have not wished to create trivial names which Linnaeus and Rivinus have given us since I realize how meagre several words are and feel that it would be most difficult to express any characteristic in a single word".

Haller's remark, however, is worth noting. The name of a plant is primarily a means of referring to it and does not necessarily give any idea of its character. Generic names and specific epithets are very commonly derived from some outstanding features of the genera and species concerned, but in many cases they are taken from the names of persons or localities. A few examples of generic names coined and explained by Linnaeus (1737, translated by Hort) are worth quoting:

"*Bauhinia* has two-lobed leaves, or two as it were growing from the same base, being called after the noble pair of brothers Bauhin.

Commelina has flowers with three petals, two of which are showy, while the third is not conspicuous, from the two botanists called Commelin, for the third died before accomplishing anything in botany.

Plumieria is a small American tree with brilliant flowers, even as Plumier was brilliant among American botanists.

Hernandia is an American tree, with the handsomest leaves of any, and less conspicuous flowers—from a botanist who had supreme good fortune and who was highly paid to investigate the natural history of America: would that the fruits of his labours had corresponded with the expenditure!

Dillenia of all plants has the showiest flower and fruit, even as Dillenius made a brilliant show among botanists.

Gronovia is a climbing plant that grasps all other plants, being called after a man who has had few rivals as a collector of plants."

By the beginning of the eighteenth century, characters of the reproductive organs were being recognised as important aids to classification and plants that resembled one another in their reproductive structures were usually treated as members of the same genus. In *Genera Plantarum,* of which the first edition was published in 1737, Linnaeus tried to do for genera what he tried to do in 1753 for species—namely, to evaluate and classify all groups previously described as genera. The genera were arranged in twenty-four classes, according to his much quoted "sexual system", based upon the number and arrangement of the stamens, the classes being subdivided according to the number of the carpels. This was an entirely artificial system that was fairly easy to use and usually allowed an unknown plant to be readily classified as to class and with little further trouble as to genus and species, although it often separated groups that were obviously closely similar. There is no doubt that Linnaeus recognized the shortcomings of the system and did a considerable amount of work towards a natural classification in which plants (and animals) are classified according to the sum of their resemblances—an ideal classification aimed at by many botanists since but probably unattainable.

Nowadays the species is regarded as the unit of classification. This unit is a concept impossible of precise, exclusive definition in a few words. Some approximations are: A species is a group (population) of individuals resembling one another more closely than they do other individuals; species are populations between any two of which there is a tangible discontinuity in morphological characters; a species is a group of individuals having essentially similar appearances, qualities and uses; a species is a kind of population.

It is now being realized that there are several different kinds of species (Camp and Gilly 1943), a realization that explains but does not overcome the difficulty of simple definition, but I do not propose to enlarge on this now. The above form of definition can, however, be used to explain a genus as a "group of species resembling one another more closely than they do other species", and genera are grouped into families in the same way. Between species and species, genus and genus, family and family there is a more or less distinct discontinuity in the sum of morphological characters. A good deal of research in classification—taxonomy—is concerned with the search for these discontinuities. Many years ago an analogy was drawn with geography. B. L. Robinson (1906) likened a family to a large archipelago of islands, the islands themselves being arranged in more or less definite groups within the archipelago. The smaller groups represent genera. Some of these groups may be separated by deep and well-defined channels, though these may be quite narrow. Others again may be more or less connected by shoals and sandbanks. The former kind represent sharply defined genera, the latter ill-defined genera. But just as an explorer may have missed the narrow though deep channels, or perhaps have run aground while exploring the broad shallows, so the systematist working on a particular family may fail to recognize a distinction between two closely similar but distinct groups of species, or be unable to segregate distinct homogeneous groups from an obviously heterogeneous collection of species. And just as more detailed exploration may lead to the discovery of navigable channels between certain members of the archipelago, so more intensive study of any family of plants often leads to the recognition of characters previously overlooked that do separate a collection of species into well-defined groups. Often, however, as shoals do exist where at a cursory glance deep water appears to be present, so groups of species often appear to be quite distinct, while on a more intensive study, the supposed distinguishing characters are found to be inconstant.

The modern taxonomist makes use of many techniques in his search for discontinuities. In the days of Linnaeus only those features observable by relatively crude microscopes were available. It is interesting to note that many of what are now considered "natural groups" were recognized well before Linnaeus, and the work of the latter was soon to be put to a severe test by the return of Banks and Solander with plants from Australia, New Zealand and the Pacific, a practically unknown region, collected on Cook's first voyage. (Solander, by the way, was a pupil of Linnaeus.) Owing to a number of circumstances, neither Banks nor Solander published any account of their plants, of which nearly 1,000 species were collected along the Australian coast. Some figures, prepared at the time, and Solander's descriptions were published long afterwards by Britten (1900-1905), but the collections in Bank's private herbarium were studied by several botanists including Robert Brown. Joseph Gaertner, one of the first to study seed structure in detail, received much of his material from Banks, whose help he gratefully acknowledged in his preface to the first of the three volumes of *De fructibus et seminibus plantarum* ... (1787-1807). Gaertner published a number of Solander's names from notes to the specimens. His work followed the Linnaean system.

R. BROWN

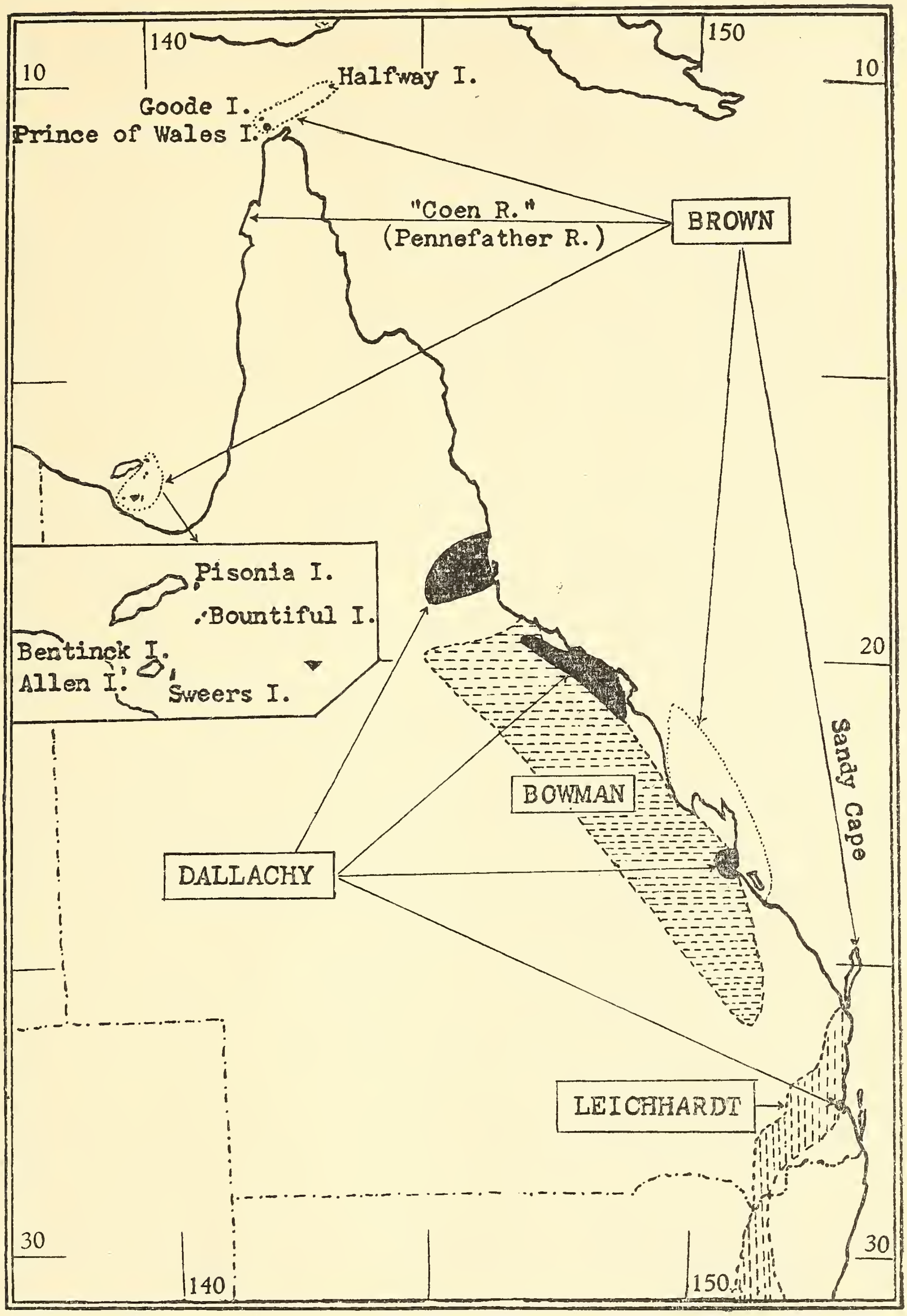
Robert Brown (1773-1858), born at Montrose, Scotland, was very early attracted to botany, studied medicine, became an Assistant Surgeon in the Army and in 1801, on the recommendation of Banks, was appointed naturalist to the *Investigator* under Captain Matthew Flinders who was to make a survey of the Australian coast. He had as assistants Ferdinand Bauer, one of the most outstanding botanical artists of all time and a skilful microscopist, and Peter Good, a gardener. The ship reached King George Sound in December, 1801, and Sydney on 9th May, 1802. Departing on 22nd July, Flinders sailed north and reached Sandy Cape, the northernmost point of Fraser Island, on 30th July, where Brown collected his first Queensland plants from what he later called the Tropical Coast. His chief localities in Queensland were Port Curtis and Facing Island, Curtis Island, Port Bowen (Port Clinton of modern maps), Shoalwater Bay, Broad Sound, three of the Percy Islands, Wigton Island (Cumberland Islands), Halfway Island and Goode Island in Torres Strait, mouth of the Pennefather River (quoted as Coen River) and five islands of the Wellesley Group, Gulf of Carpentaria. He did not visit the Endeavour River although he has been quoted as collector of some specimens from this locality.

After the *Investigator* returned to Sydney he remained in Australia nearly two years longer collecting in the neighbourhood of Sydney, about the Hunter River, in Tasmania (chiefly around Hobart and Launceston), the islands of Bass Strait and Port Phillip. He arrived back in England in October 1805, with a collection representing nearly 3,900 species of plants.

Brown kept a diary of his travels, which is now in the British Museum of Natural History. Through the activities of the Systematic Botany Committee of the Australian and New Zealand Association for the Advancement of Science microfilm copies are now in the major Australian herbaria and it is from this diary and Flinders's journal that Brown's collecting places have been mapped (text-figs. 1 and 4). All plants were described while still fresh, usually under some provisional name for reference. Many such descriptions are in the diary. Brown also entered descriptions of the country with notes on geology, soils, some zoology and the aborigines. There are several references to country being recently burnt.

After his return to England he remained on the books of the *Investigator* until 1810 when he became librarian to Banks and curator of his herbarium. On the death of Banks he joined the staff of the British Museum.

He had already begun publishing the series of works for which he became famous. One of the best known is the *Prodromus Florae Novae Hollandiae,* an account of all plants then known from Australia based chiefly on his own collections and those of Banks and Solander. In this, the descriptions of many of the species discovered by Banks



Text-fig. 1.—Map of Queensland showing the areas in which Brown, Leichhardt (1843-4), Dallachy, and Bowman collected. Locality names are those not shown on Text-figs. 2-4. The inset shows "Carpentaria Islands a—e"; a, Sweers Island; b, Bentinck Island; c, Allen Island; d, Bountiful Island; and e, Pisonia Island.

and Solander were first published. The first of the two parts planned was published in 1810, not later than the end of March, at Brown's own expense and in an edition of 250 copies. The work sold badly and Brown was so disappointed that he would not go on with the second part. There is a tradition that Brown's action was prompted by an adverse criticism of the Latin (in which the work is written) but there seems to be no evidence for this story (Britten 1907). For the *Prodromus* "he found it necessary to choose whether to accept the convenient artificial system devised by Linnaeus and which held almost unquestionable sway in Britain, or to seek to discover the natural affinities of plants and to base the classification upon these'' (Asa Gray, quoted by Maiden 1909). He chose the latter, basing his work on that of Jussieu (1789) and ''by his sense of the relative values of the different parts of the plants for discriminating the genera and species, the exactness of his descriptions, and his philosophic views of the affinities of plants, he did more than anyone else to improve and establish the natural system of plants. He was painfully careful for accuracy in all his work'' (Carruthers 1896). In an appendix to Flinders's journal (Flinders 1814) he gave the first published account of the relationships of the Australian flora. I do not intend to enlarge on this or his well known work on the Apocynaceae and Asclepiadaceae, the Proteaceae and other families, but I would like to recall that he discovered the nucleus, the streaming of protoplasm, and the Brownian movement known to physicists and chemists.

I would also like to recall the fact that Brown was the first to attempt a natural classification of the grasses. Brown's broad classification set out in the *Prodromus* is essentially that which is most generally accepted by modern agrostologists. The enormous increase in the sum total of discovery, observation and experience in the past 140 years have certainly resulted in many alterations and refinements in the classification of the Gramineae, but it is remarkable how well Brown's system has stood the test. The descriptions in the *Prodromus* are brief, but Brown had a genius for emphasizing the outstanding characters of a family, genus, or species in a few carefully chosen words.

The collection of living plants made on the voyage round Australia, together with the best set of his specimens from the south coast were lost in the wreck of the *Porpoise* at Wreck Reef in August, 1803. But the remainder of the dried specimens and at least some of the animals and rocks and his later collections reached England safely. Little was done with the zoological and geological material. A set of the plants was placed in the Banksian Herbarium and some specimens were distributed. Brown's own herbarium and the Banksian Herbarium eventually became part of the Herbarium of the British Museum of Natural History. After Brown's death many duplicates were distributed by direction of J. J. Bennett from the British Museum of Natural History. The specimens were apparently sorted according to species, not always accurately, those of each supposed species being given the same serial number no matter when and where they were collected, and distributed in sets. I have also seen specimens distributed from the Royal Botanic Gardens, Edinburgh, and in some Australian herbaria are specimens with narrow whitish labels written up by Daniel Oliver bearing only a name determined from Bentham's *Flora Australiensis* and usually some locality name.

BENTHAM

George Bentham (1800-1884) went to Russia with his parents while still a child and later lived in France. He began learning Latin before he was five, and at seven could converse fluently in English, French, German, and Russian; shortly after he acquired a working knowledge of Swedish in a few weeks, to which, in later life he added Hebrew and Spanish. From his uncle Jeremy Bentham, the publicist, he early acquired the love for methodical and logical analysis so conspicuous in his writings. While on a caravan tour of France with his parents in

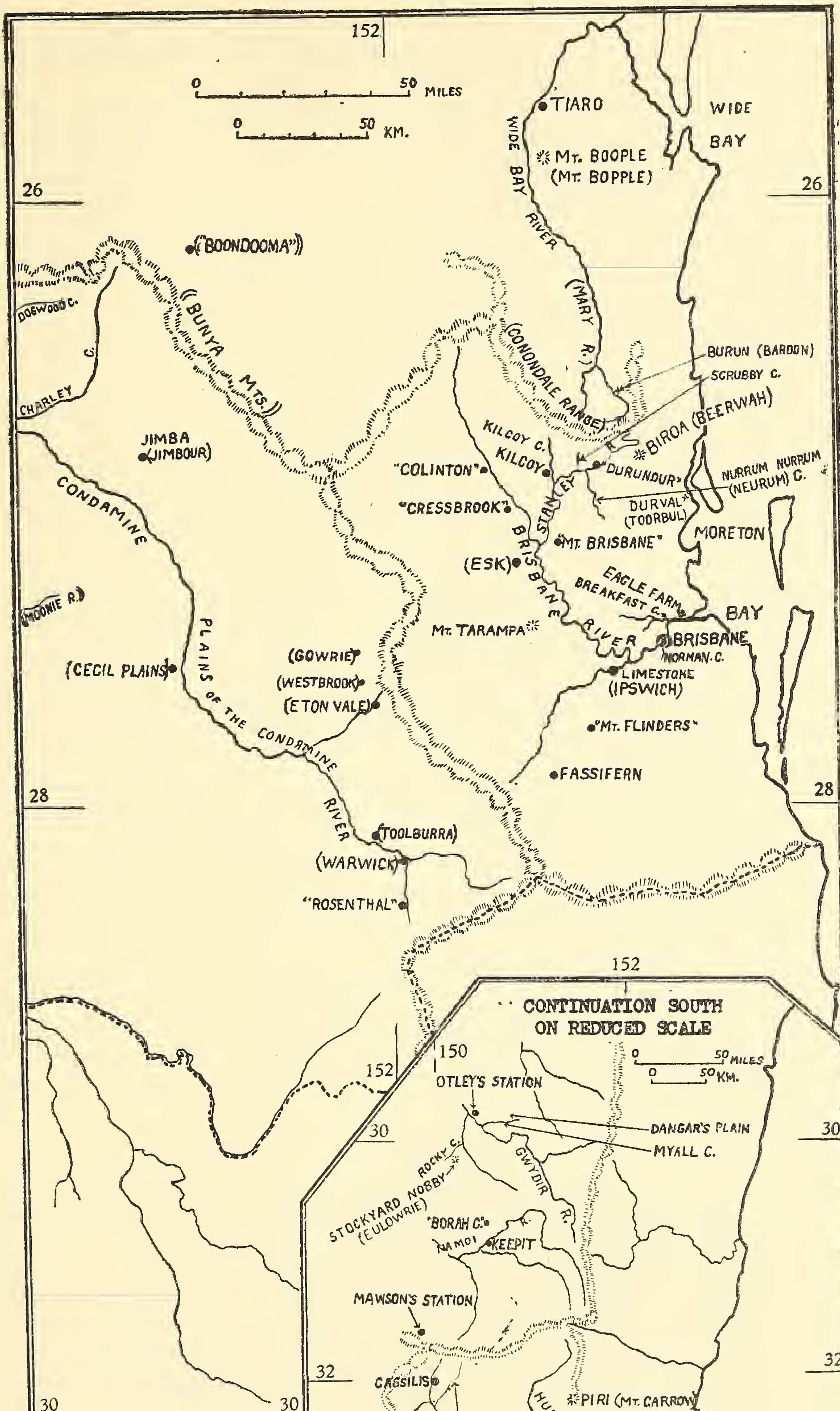
1816, he became acquainted with de Candolle's *Flore Française.* He became interested in the analytical table for identifying the plants, tried it out and took up the study of the local flora as a diversion.

While on a visit to England in 1823 he made the acquaintance of Banks, R. Brown, W. J. Hooker and other well known botanists of the day, and from this period dates his permanent adherance to botany. He commenced a life-long friendship with Brown and Hooker and later with Hooker's son, J. D. Hooker, who wrote an account of his work (1898). In 1826 he returned to England for good, became secretary to Jeremy Bentham, studied law, logic and jurisprudence and published papers on these subjects. He became financially independent after the death of his father in 1830 and from about 1832 onwards devoted himself entirely to botany. Many monographs and revisions as well as other works were published in the next 22 years. In 1854, finding that the cost of keeping up his herbarium and library was more than he could afford, he presented them to the Royal Botanic Gardens at Kew and would have abandoned botany altogether but for the earnest persuasion of his friends. W. J. Hooker, then in charge of Kew, persuaded him to continue his work at that institution. From 1855 he spent five days a week at Kew from 10 a.m. to 4 p.m., without a midday meal, and at night wrote up the notes of his day's work. "With such methodical habits, with freedom from professional or administrative functions, which consume the time of most botanists, with steady devotion to his chosen work, and with nearly all authentic material and needful appliances at hand or within reach, it is not surprising that he should have undertaken and have so well accomplished such a vast amount of work, and he has the crowning merit and happy fortune of having completed all that he undertook" (A. Gray, quoted by Hooker, 1898). During this period he wrote *Flora Australiensis* and, with J. D. Hooker, *Genera Plantarum,* two classic works by which he is best known to Australian botanists. *Flora Australiensis* is the first flora of any large continental area to be finished. It consists of seven volumes containing the descriptions of about 7,000 species. It was begun in 1861 and finished in 1878. Bentham wrote this and his share of *Genera Plantarum* (1862-83) with a single gold nib which broke shortly afterwards while he was writing an autobiography; he died some months later. It is not easy to exaggerate the importance of *Flora Australiensis,* and most work since on the flora of Australia has been based directly or indirectly on it. Bentham worked out the classifications now used for *Acacia, Eucalyptus* and several other especially difficult groups.

As he explained in his preface, he examined for the work the great majority of specimens that had ever been collected in Australia. Here and elsewhere (Bentham 1883) he made special mention of the specimens and MS. notes of Banks and Solander and R. Brown and quoted a large number of their collections, yet it has been stated more than once (e.g. Britten 1906) that Bentham partly or entirely ignored these collections! He examined also the large collections in the National Herbarium of Victoria, brought together by the activity and influence of Ferdinand Mueller (later von Mueller). The great help he received from this herbarium induced him to acknowledge Mueller's assistance on the title page. Because of this, Mueller has been treated as co-author by some. But Bentham alone was reponsible for the descriptions and opinions expressed (Bentham 1883), and he alone should be cited as author. Mueller himself collected a large proportion of these specimens from many parts of Australia, and many were collected by others at his suggestion, often at his expense. The labels of specimens collected by local travellers or residents often carry locality names not always understood by Mueller and often not to be found on the average map. In many cases the collector's rough label was preserved as well as a herbarium label with Mueller's name printed on it, and on this Mueller wrote the name of the plant, the locality (often indicated by some generalized term) and the collector's name, the last often abbreviated and sometimes omitted. Such labels were distributed with duplicate specimens and it is not surprising that many localities have been misquoted in works published overseas and the collector often quoted as Mueller. For a number of years now I have been recording whatever was written on the field labels to specimens collected by Leichhardt, Dallachy and Bowman examined in the Melbourne Herbarium or received on loan from that institution for my studies of various groups, and I have searched *Flora Australiensis* and Mueller's *Fragmenta* (1858-82) for other localities. Some of these names are no longer in use and the spelling of others has been modified, but references to early maps and historical records and the known distribution of recorded species have made it possible to map most localities that have been mentioned (Text-figs. 2-4).

LEICHHARDT

Fredrich Wilhelm Ludwig Leichhardt (1813-1848) was born at Trebalsch, Prussia, and arrived in Sydney in February 1842. He travelled extensively in eastern Australia and became famous as an explorer from his overland expedition from Sydney to Port Essington in 1844-5, and his tragic attempt to cross Australia from east to west in 1848. He collected plant specimens wherever he went and sent a large number to Paris. His own herbarium was presented to the Sydney Museum by his friend Robert Lynd and later sent to Melbourne to be examined by Mueller at the latter's request; only a few specimens were returned to Sydney, and they are now in the National Herbarium of New South Wales (Maiden 1908). Mueller first mentioned them in the nineteenth fascicle of his *Fragmenta* published in July, 1862, and it is reasonable to suppose that he received them shortly before this date. Most specimens carry small field labels, often written in pencil, giving the locality and date. Many of those collected on the way to Port Essington were lost before the journey was over, and whatever was obtained on the last expedition perished with the party. The specimens I have seen are chiefly from the neighbourhood of the Hunter River, New South Wales, and south-eastern Queensland. The localities are now difficult to interpret, especially those of the years 1842-4 which were written in the style of ''Mr. Archer's Creek'', ''Mr. Balfour's Sugarloaf'', etc. I have succeeded in placing most of these localities by a comparison of dates, letters (Politzer 1944), published accounts (Bracker 1927, Hall—, M'Connell 1932, McConnell—, Meston 1895), early records of pastoral licenses from the New South Wales Government Gazettes for 1841-4, and a posthumously published geological work (Leichhardt 1855). He left ''Mr. Scott's'' (''Glendon'') on the Hunter River, N.S.W., in March, 1843, made his way north via New England and the Darling Downs and was in Brisbane by June. The following localities named on labels dated June or July are within the limits of the present city of Brisbane:—Eagle Farm, Breakfast Creek, Norman Creek and Three Mile Brush (now Bancroft Park). In July and early August he made



Text-fig. 2.—Map showing Leichhardt's collecting localities in 1843-4. Where two names are given for a locality, the first is the name used by Leichhardt, the second (in parenthesis) is the one appearing on modern maps; variations in spelling have been omitted. Names in double parentheses have nothing to do with Leichhardt; they are explained in the text.

his way to "Eale's Station" ("Tiaro") near Maryborough after crossing the "Bunya Bunya" (Conondale Range, not the Bunya Mountains of modern maps), possibly after he had established himself at "Archer's Station" ("Durundur" or sometimes written "Durandur") which he made his headquarters until the following February. He collected at "McKenzie's Station" ("Kilcoy"), "Balfour's" ("Colinton"), "McConnell's" (or M'Connell's) ("Cressbrook"), "Bigge's" ("Mt. Brisbane") and "Scott's" ("Mt. Esk") (to be distinguished from the Scott of "Glendon"). He was on the Darling Downs in March having collected at "Limestone" (Ipswich) on the 7th, "Mr. Wilson's Lagoon" ("Mt. Flinders" Station) on the 20th and "Mr. Bracker's" ("Rosenthal", near where the town of Warwick is now) on the 26th. (Text-figs. 1 and 2).

He returned to Glendon in May 1844 by way of New England, Apsley River, Gloucester and Stroud. It was found desirable to map in the localities in New South Wales (see inset to Text-fig. 2), but for these I have had to rely largely on Leichhardt's own account (Leichhardt 1855) and have not always been able to identify them with modern names.

Several spellings of some names have been found; some appear to have been Leichhardt's attempts to spell names he had only heard and some are obvious typographic errors, but it is scarcely practicable to list all these variations. A few are worthy of note. Nurrum Nurrum (Narum, Mirum Mirum) is the modern Neurum (township, mountain and creek). Tarampa Hill or Tarama Hill is Mount Tarampa. Biroa (Beroa, Biron) is Beerwah, the highest of the Glasshouse Mountains. Mt. Esk Station is not found on modern maps; it was a little to the north-west of the site of the present town of Esk. As already mentioned, Bunya Bunya (or Bunya Bunya brush) is the Conondale Range; Mueller wrote for this "Araucaria forests on the Dawson and Burnett Rivers" or some similar phrase, and this was copied by Bentham. Durval seems to be the modern Toorbul.

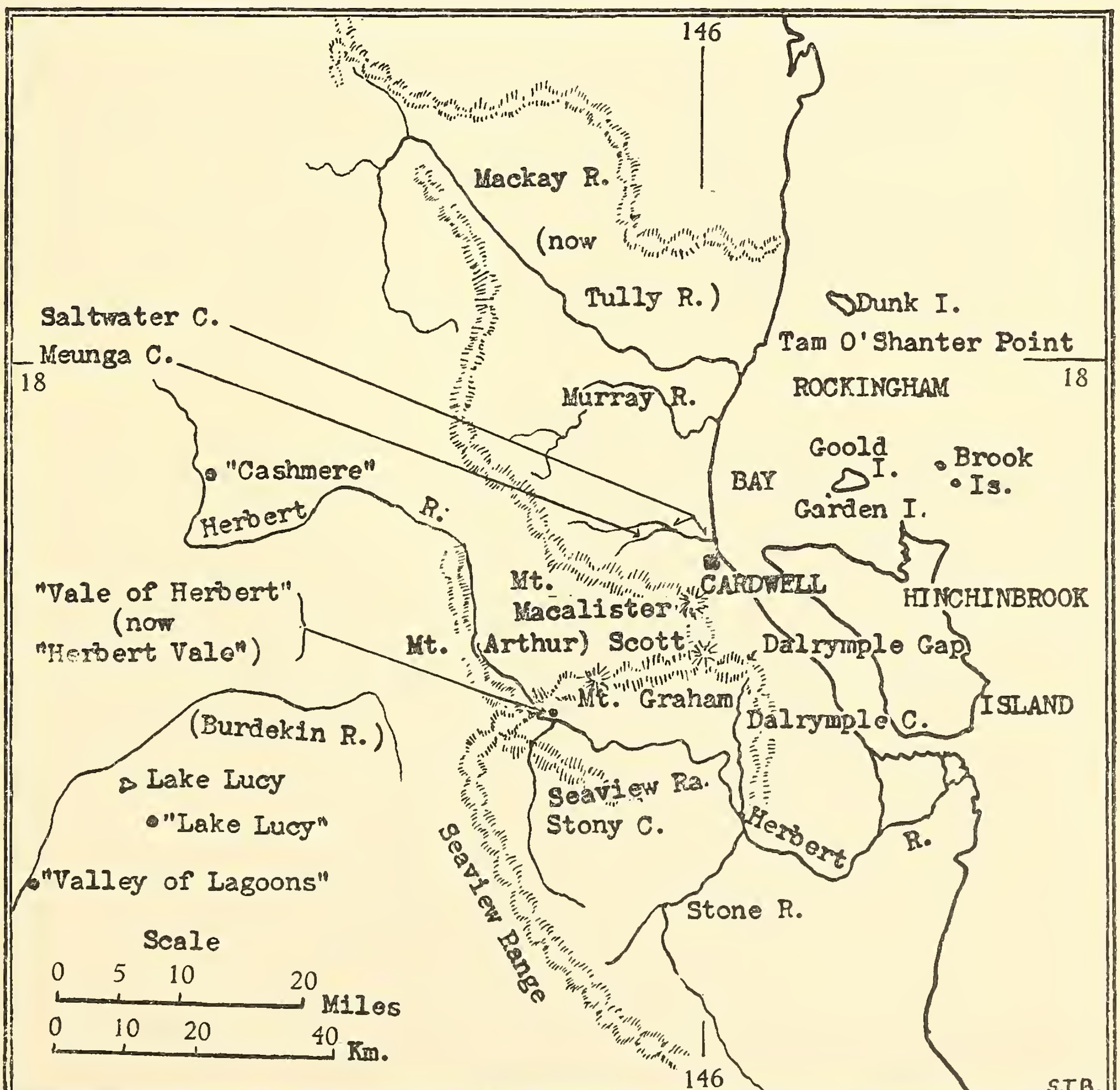
Where a township now exists close to a cattle or sheep station visited by Leichhardt this is shown for preference on the map; if the name was not used by Leichhardt it is shown in parentheses. A few localities visited in late 1844 on his journey to Port Essington are marked; those to the west and north can usually be found on a good large scale map.

DALLACHY

John Dallachy (1820(?)-1871) was born in the North of Scotland and was a professional gardener before coming to Australia. In 1849, shortly after his arrival in this country, he was appointed Superintendent of the Melbourne Botanic Gardens, but lost his position to Ferdinand Mueller in 1857 (Maiden 1908A). Shortly after, he became a collector of plants for Mueller, firstly in Victoria and south-western New South Wales and then in Queensland, chiefly in the neighbourhood of Cardwell. He died on 4th June, 1871, at "Vale of Herbert" ("Herbert Vale"), about 18 miles south-west of Cardwell, on the Herbert River.

Dallachy was a fruitful collector and his collections from north-eastern Queensland did much to make known the rich flora of this region (Text-figs. 1, 3 and 4). His collections are for the most part copious, and the specimens well selected, well preserved and carefully annotated. Mueller described a large number of new species from his collections and usually made use of Dallachy's notes on the habit of the plant. However, for the majority of plants sent from Cardwell, the locality was cited merely as ''Rockingham Bay.'' This was the only indications of locality ever entered on herbarium labels, and the labels accompanying many of the duplicates distributed by Mueller to European herbaria apparently did not even have the collector's name, if one may judge from the number of references to plants from Rockingham Bay said to have been collected by Mueller that appear in European publications. Mueller never collected anywhere near Rockingham Bay. Some of the specimens cited from this locality came from up to 220 miles away. From the examination of Dallachy's original labels to specimens in the National Herbarium of Victoria, Melbourne, I have been able to work out his movements after he left Victoria.

On his way from Melbourne to Cardwell, Dallachy collected about Brisbane in December, 1862, in the neighbourhood of Rockhampton from early January 1863 (at least from the 5th) to at least April 16th, in the neighbourhood of Bowen from at least June 11th to at least September 2nd. He visited Mt. Elliot in August and was at Proserpine Creek and Mt. Mueller (Mt. Miller on modern maps) on September 10th. He seems to have arrived in Cardwell towards the end of the year, and this remained his headquarters until his death.

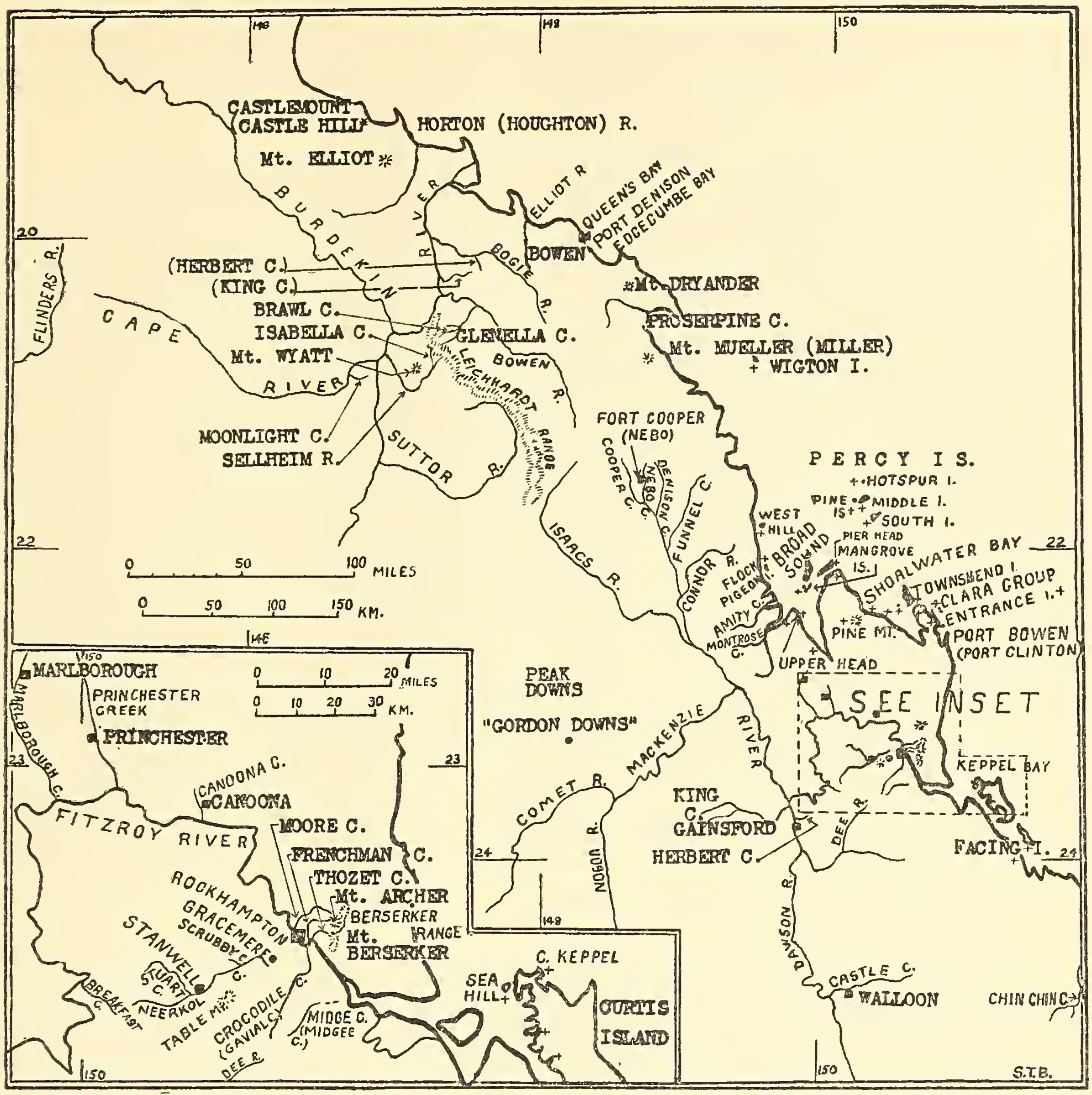


Text-fig. 3.—Map showing Dallachy's collecting localities about Rockingham Bay. The ''Sugar Plantation'' was on the south bank of the Murray River, near the letters ''r'' and ''a''.

In October, 1866, he went south to the Herbert and Stone Rivers and to Stanley Plains near Townsville (?). He evidently met Thozet when in Rockhampton, and some of his specimens are from Thozet Creek. The locality for most specimens from this area is quoted in literature as Rockhampton. His specimens from Bowen are labelled Queen's Bay, Edgecumbe Bay or Port Denison, most of them being written up by Mueller as Port Denison, and commonly cited as such, but those from Proserpine Creek and Mt. Mueller are quoted from ''Rockingham Bay'' (Text-fig. 4). Some of his collecting in this area was done in company with Fitzalan, a pioneer resident of the recently formed settlement of Bowen, who collected extensively in the area. While living at Cardwell, Dallachy collected along the coastal belt from the northernmost point of Rockingham Bay (Tam o'Shanter Point) south nearly to Townsville, on the coastal ranges (Coast Range and Seaview Range, the former apparently the Mount Elphinstone Range and Cardwell Range of modern maps), Mt. Graham and Dalrymple Gap, and visited ''Cashmere'' and Lake Lucy on the western slope (Text-fig. 3). Some specimens were collected on the Mackay River and the Murray River, two small streams flowing into Rockingham Bay north of Cardwell. There has been confusion between this Murray River and the better known Murray River forming the boundary between New South Wales and Victoria, along which Dallachy had collected earlier in 1858. The Mackay River is now known as the Tully River and has nothing to do with the present town of Mackay, though I have been told that the Pioneer River on which the latter stands was at one time known as the Mackay River. Saltwater Creek is that part of Meunga Creek below its junction with Kennedy Creek. There are at least three creeks in the district called ''Stony Creek'' but the one where Dallachy collected is almost certainly the tributary of the Herbert River, joining with the latter near ''Herbert Vale,'' near the old track to the Valley of Lagoons along which Dallachy collected. The Stone River, another collecting area, is also a tributary of the Herbert. Glendalough (Rockingham Bay), Mt. Buzzard (near Rockhampton) and Maria Island have not been traced.

BOWMAN

Edward Macarthur Bowman (1826-1872) collected widely in central-eastern Queensland, but I have found very little about the man himself. His specimens are mostly small, with small slips of whitish paper marked with a number and locality, very rarely with a date (from 1862 to 1871). The specimens were not numbered in simple sequence, for the same number has been found given to sepcimens from different localities or specimens of quite different genera. Many of them were collected in the general neighbourhood of Rockhampton, but he collected over a large part of the basins of the Fitzroy and Burdekin Rivers. His localities (Text-figs. 1 and 4) are more difficult to place than Dallachy's or Leichhardt's because in several cases the same name has been applied to two or three different features in the area and some names also apply to much better known features in other parts of Queensland. His Cooper's Creek, for example, is a relatively small tributary of Nebo Creek, one of the tributaries of the Isaacs River, not the well-known stream of south-western Queensland and north-eastern South Australia. Bowman's Elliot River is certainly the one near Bowen, not the Elliott (originally Elliot) River near Bundaberg. There is a place near the mouth of the Burdekin River called ''Gainsford'' that is marked on some



Text-fig. 4.—Map showing (1), Brown's collecting localities in the neighbourhood of Keppel Bay, Shoalwater Bay and Broad Sound (marked with a cross); (2), Dallachy's collecting localities in the neighbourhood of Edgecumbe Bay and of Rockhampton; and (3), Bowman's collecting localities except for Moonie River and Boondooma (see Text-fig. 2).

maps, but this name did not come into use until after Bowman's death. Near each "Gainsford" is a Herbert's Creek and a King's Creek, frequently cited localities, and there is a third Herbert's Creek flowing into Broad Sound, another name that occurs on Bowman's labels. There is a third Gainsford, also of later date, north-west of Charters Towers. Neerkol Creek (near Rockhampton) is often cited as Nercool, Neercool or Neerkool Creek. Midge Creek is now Midgee Creek and Wedge Creek is possibly a misreading of the same name. Castlemount or Castle Mount is now Castle Hill, at Townsville. Fort Cooper is now Nebo. Moonie River is shown on the western edge of Text-fig. 2 and Boondooma towards the north-western corner. Mulholland Creek has not been traced. Herbert's Creek is now Herbert Creek.

Text-fig. 4, especially the inset, also shows most of the localities where P. O'Shanesy collected in the years 1867-76.

MAIDEN

Joseph Henry Maiden (1859-1925) was born in London and came to Sydney in 1880. He helped to form the Technological Museum of New South Wales in 1881 and was curator until 1896 when he became

Director of the Sydney Botanic Gardens and Government Botanist of New South Wales. He founded the National Herbarium of New South Wales.

He wrote on a wide variety of subjects and took considerable pains with a series of papers on Australian botanists and botanical collectors, some of which have been used in preparing part of this address. He made a special study of the two great Australian genera *Eucalyptus* and *Acacia*. The work on the latter genus appeared in various publications. In 1903 appeared the first of the seventy-five parts of *A Critical Revision of the Genus Eucalyptus*. In this work, Maiden brought together nearly everything that had been published on the genus, illustrating it with a vast number of excellent figures of types and other specimens. The work is a mine of information for anybody interested in these plants, but it offers little help, by itself, to anyone wishing to classify a particular plant. Species or groups of species were dealt with in no definite order, but rather as Maiden's ideas on the groups crystallized. No general classification, synopsis or key was provided. Perhaps he died too soon (eleven parts were unpublished at the time of his death), but so much in his writings suggests that such a task may have been beyond his particular ability. His gathering together of relevant literature, the number and excellence of the illustrations, his activity in the field and the interest in the genus he inspired in others have provided a broad foundation for the workers who came after him. The title page of each volume of the *Critical Revision* carries a quotation from Macaulay with which I would like to close:

"Ages are spent in collecting materials, ages more in separating and combining them. Even when a system has been formed, there is still something to add, to alter, or to reject. Every generation enjoys the use of a vast hoard bequeathed to it by antiquity and transmits that hoard, augmented by fresh acquisitions, to future ages. In these pursuits, therefore, the first speculators lie under great disadvantages and even when they fail, are entitled to praise."

ACKNOWLEDGEMENTS

Mr. J. L. Pring, Oxley Librarian, Brisbane, traced some of the publications concerning Leichhardt. The Registrar-General's Department, Brisbane, provided the details concerning Dallachy that appear on his death certificate. A great-grandson of Dallachy, Mr. F. G. Skardon, Tully, provided some other details, and he and Mr. S. E. Stephens, Cairns, helped in identifying some of the geographical names in local use around Cardwell. Mr. D. F. Lilier and Mr. W. Gould helped with some localities near Newcastle. Mr. W. L. Wegner, Survey Office, Brisbane, allowed me to consult early maps and obtained information concerning the dates of origin of some names. Associate Professor F. W. Whitehouse lent me one of Leichhardt's works.

SUMMARY

The first account of Australian plants was published by Dampier in 1703. May 1753 is the date of publication of *Species Plantarum* and is the accepted starting point of modern nomenclature for most groups of plants. The name of the species is formed of the name of the genus followed by a specific epithet instead of the often long and cumbrous descriptive phrase previously used; the concept of the genus and generic

name developed much earlier. The genus at first became the unit of classification but nowadays the accent has shifted to the species. Linnaeus devised an artificial system of classification of genera and worked towards a natural system that was further elaborated by Jussieu and stabilized by R. Brown. Brown visited a number of places along the Australian coast in 1801-3 and explored extensively around Sydney, the Hunter River and Tasmania. His localities in Queensland have been mapped from his diary. Bentham is best known to Australian botanists by his *Flora Australiensis* (1863-78) and (with J. D. Hooker) *Genera Plantarum.* He was the first to propose comprehensive classifications of many large families and genera. J. H. Maiden aroused great interest in the genus *Eucalyptus,* on which he did a great deal of work. He brought together most of what had been published in the excellently illustrated *A critical revision of the genus* Eucalyptus, but did not offer a key or comprehensive classification. Leichhardt, Bowman and Dallachy were important early collectors. Leichhardt collected in south-east Queensland in 1843-4, Bowman in central eastern Queensland about 1862-71 and Dallachy chiefly about Rockhampton, Bowen and "Rockingham Bay" from 1863 to 1871. The collecting localities of these three collectors are often difficult or impossible to find on modern maps, but most of those found on labels or in published citations of specimens have been located and mapped.

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Vol. LXVI., No. 2.

IXODES CORDIFER NEUMANN 1908 (IXODIDES : ACARINA)

A DESCRIPTION OF THE FEMALE AND A REDESCRIPTION OF THE MALE.

(With two Text-figures.)

By F. H. S. Roberts.*

(*Received 8th June,* 1954; *issued separately,* 5*th September,* 1955.)

Several ticks sent from Papua to Mr. P. J. O'Sullivan, Parasitologist, Animal Health Station, Yeerongpilly, for identification have proved to be *Ixodes cordifer* Neumann. Neumann's description of this species was based on a single male taken from an unknown host at Sekroe, Dutch New Guinea. The species is included by Nuttall *et al.* (1911) in their revision of the genus *Ixodes,* by Krijgsman and Ponto (1932) in their paper on ticks occurring in the East Indian Archipelago, and by Fielding (1926) and Taylor (1946) in their respective papers on Australasian ticks. None of these workers examined specimens, and their descriptions were based on Neumann's original work.

The material now available consists of three males and eleven females, and as it would seem that the species has not been collected since Neumann described the male in 1908, a description of the female and a redescription of the male are provided.

Ixodes cordifer Neumann.

Ixodes cordifer Neumann, 1908, p. 73, fig. 1; Nuttall *et al,* 1911, p. 233, fig. 229; Fielding, 1926, p. 48, fig. 16; Krijgsman and Ponto, 1932, p. 28, fig. 45; Taylor, p. 47, fig. 49.

Male, Figure 1, a-d.

Diagnosis. Oval, of medium size, with distinct marginal fold posteriorly only; scutum with fine, mainly marginal, punctations and with linear and inconspicuous lateral carinae; palps short and broad, hypostome dentition 2/2; venter with median plate broadest posteriorly, the anal plate cordate and pointed behind; coxae I-III each with two spurs, the internal spur not conspicuous; coxa IV with a single, pointed spur; trochanters each with a single spur, best developed on trochanter IV.

Description. Body 2.6-2.8 mm. by 1.9-2.0 mm.; yellowish, darker along margins of scutum, oval, widest in region of spiracles and approximtately three to four times as wide as the emargination.

Scutum yellowish and covering almost all dorsum, with scattered, fine, minute hairs; a broad, smooth depression on each side extending for one half to two thirds of the scutal length, limited laterally by the

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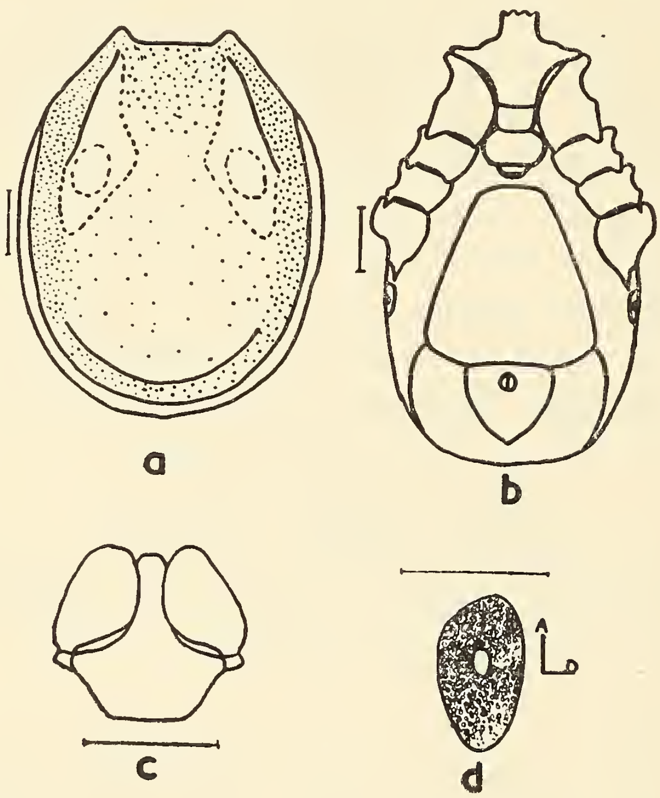
lateral carinae which are short, linear and not very distinct; emargination moderate, scapulae bluntly pointed; punctations fine, few medianly, but numerous along margins of scutum, particularly between the lateral carinae and lateral margins; cervical grooves short, convergent, superficial; marginal fold distinct posteriorly only.

Capitulum 0.6-0.64 mm. in length; width at posterior border of basis capituli 0.36-0.43 mm.; basis dorsally finely punctate, pentagonal, the posterior border straight and without cornua; auriculae absent; palpi 0.5 mm. long, article 1 transverse, articles 2 and 3 apparently fused, constricted at base and broad dorsally attaining a width of about half the length; hypostome 0.30 mm. long, dentition 2/2 with four or five rows of broad, rounded teeth, the posterior rows very shallow and ridge-like.



Text fig. 1. *Ixodes cordifer* (male). a, scutum, the dotted lines enclose the depressed areas; b, venter; c, capitulum (dorsal view); d, spiracular plate. The straight lines each represent 0.5 mm.

Venter concave, with scattered, pale, short hairs, most conspicuous near spiracles; genital oriface broad, between coxae II; pregenital plate broader than long; median plate 1.4 mm. long, broadest posteriorly (1.07 mm.) where it is three times the width anteriorly; adanal plates slightly concave anteriorly, curved posteriorly to fuse behind the point of the anal plate, the posterior border wider than the anterior border; anal plate somewhat cordiform, as board as long (0.53 by 0.53 mm.) and pointed posteriorly, the anterior margin straight or slightly convex.

Spiracular plate oval, longer than broad, 0.5 mm. by 0.22 mm.

Legs yellow and of moderate length; coxae broad, flat and contiguous or almost so with a few long hairs on the posterior borders; coxae I-III with a medium sized spur at the postero-external angle and a shallow inconspicuous spur at the postero-internal angle, both spurs most prominent on coxa I; coxa IV with a single conspicuous, pointed spur; trochanters I-IV each with a single spur, difficult to detect on trochanter I and increasing in size posteriorly; tarsi 0.68-0.72 mm. long, tapering somewhat abruptly; pulvillus not quite as long as claw.

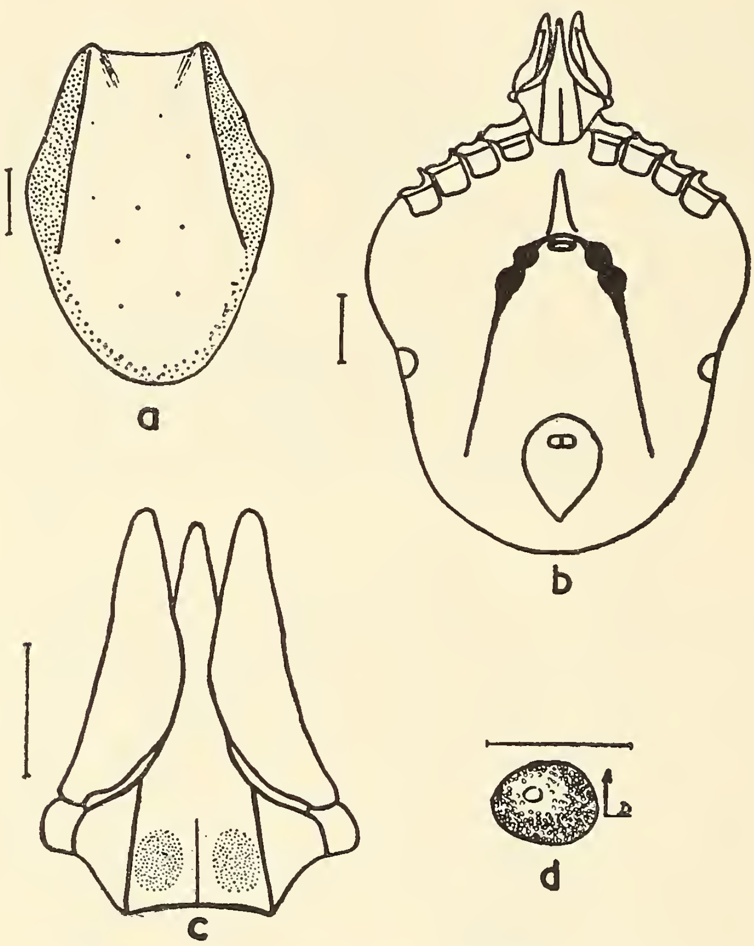
Female, Figure 2, a-d.

Diagnosis. Of medium size, partially engorged specimens being very broad anteriorly, narrowing suddenly in width in region of spiracles; marginal fold visible only laterally and disappearing on engorgement; scutum longer than broad, with well developed lateral carinae; basis capituli pentagonal with three longitudinal ridges dorsally and ventrally; porose areas oval, inconspicuous; palpi elongate; an elongate, triangular depression anterior to the genital opening; anal grooves broadly pyriform and meeting behind anus; coxae with longitudinal ridges and a single moderate-sized spur at the postero-external angle.

Description. Body of unfed specimens, yellowish, oval, 3.2 mm. by 2.3 mm., widest in region of spiracles; partly engorged specimens greyish, very wide anteriorly and narrowing suddenly immediately anterior to spiracles; engorged specimens reddish, 11.2 mm. by 8.6 mm., elongate, oval, about equally thick at both ends; body hairs sparse, minute and pale; marginal groove deep and conspicuous in unfed specimens, but not attaining the posterior margin of body and disappearing on engorgement; lateral and median grooves well developed in engorged specimens.

Scutum yellow, with darker lateral margins, 2.3-2.5 mm. by 1.8-2.0 mm., longer than broad, broadest at about its middle, flat medianly and convex laterally, antero-lateral margins slightly sinuous, postero-lateral margins slightly convex; scapulae rounded, the emargination shallow; punctations fine, few medianly, distributed mainly around margins, most numerous and slightly coarser external to the lateral carinae; lateral carinae prominent, not quite attaining the postero-lateral margins; cervical grooves, short, convergent and superficial.

Capitulum length 1.1-1.3 mm.; width at posterior border of basis capituli 0.53 mm.; basis capituli pentagonal, posterior border concave, with a prominent lateral ridge dorsally on each side, extending from the postero-lateral angle to base of hypostome and making the postero-lateral angles prominent; a less prominent median ridge extending forward between the porose area for about half the length of the basis capituli; similar ridges ventrally, lateral ridges highly developed posteriorly, median ridge longer than its dorsal counterpart; porose areas oval, of moderate size, shallow and inconspicuous, the interval slightly less than their width; palpi 0.9-1.1 mm. long, projecting slightly beyond tip of hypostome, article 1 transverse, articles 2 and 3 apparently fused, elongate, widest medianly; hypostome somewhat lanceolate, dentition 3/3 and 2/2, the inner file of 16 to 18 minute teeth disappearing posteriorly; middle and outer files of eight or nine teeth, the outer file most developed and composed of large, pointed teeth.



Text fig. 2. *Ixodes cordifer* (female). a, scutum; b, venter of semi-engorged specimen; c, capitulum (dorsal view); d, spiracular plate. The straight lines each represent 0.5 mm.

Venter with genital opening posterior to coxa IV, preceded by an elongate, triangular depression; genital groove conspicuous, very deep for a short distance below genital oriface where it may form deep, circular cavities on each side; anal groove broadly pyriform and meeting at a point behind the anus; body hairs sparse, pale, minute, most conspicuous in unfed specimens near the spiracles.

Spiracular plate broadly ovoid, and broader than long, 0.43 by 0.50 mm.

Legs yellow and of median length; coxae contiguous in unfed specimens but becoming slightly separated as engorgement proceeds; coxa I with two prominent longitudinal ridges; coxae II to IV each with one similar ridge less prominent on coxa IV; a single, conspicuous, medium sized spur at the postero-external angle decreasing in size posteriorly; tarsi as in male.

MATERIAL EXAMINED AND DESCRIBED.

PAPUA: Sogeri, 10-XI-51, 1♂ 4♀, J. Barrett; Sogeri, 28-XI-51, 1♂ 4♀, J. Barrett; Sogeri, 7-XII-51, 1♂ 3♀, J. Barrett. All specimens were collected from "wallabies".

Little is known of the ticks occurring in New Guinea. Twelve species have been recorded (Nuttall *et al* 1908, 1911, 1915, 1916; Robinson 1926; Krijgsman and Ponto 1932) including two species of *Ixodes*, namely *I. eichhorni* Nuttall and *I. cordifer* Neumann. The latter is distinctive, and among the Australasian species appears closest to *I. holocyclus* Neumann. There is no danger of confusing the two species, however; the males may be readily separated by differences in the anal groove, coxal armature, marginal fold and lateral carinae, and the females by differences in the marginal fold, the auriculae, the longitudinal ridges on the basis capituli and the number and disposal of the teeth on the hypostome.

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Vol. LXVI., No. 3.

SPHERULITES AND ALLIED STRUCTURES, PART III.*

By W. H. Bryan, Department of Geology, University of Queensland.

(With three Plates and one Text-figure.)

(*Received 8th June*, 1954; *issued separately*, 5*th September*, 1955.)

VI. APPLE-SHAPED SPHERULITES FROM CAPE HILLSBOROUGH.

1. Description.

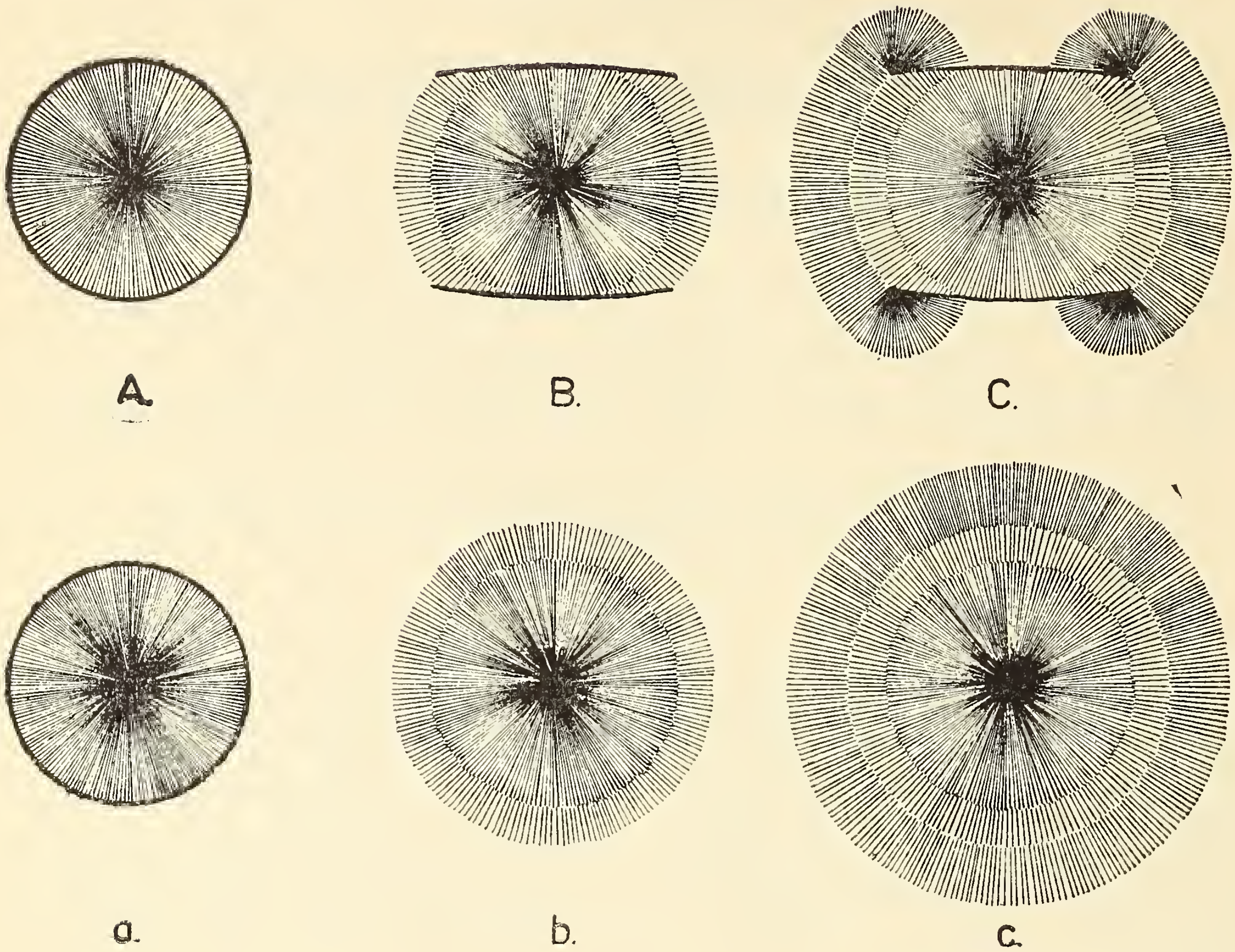
The spherulites now to be described consist of material collected by Mr. J. H. Williams of Mackay. They were obtained some ten years ago in somewhat rugged country near Cape Hillsborough, on the Queensland coast, 600 miles north-west of Brisbane and about 20 miles north-north-west of the city of Mackay. Only two hand-specimens were collected at the time, and subsequent visits to the area by Mr. Williams and by my colleague Professor F. W. Whitehouse have failed to rediscover the outcrop, so that the field occurrence unfortunately is not known.

The specimen described (Plate I.) is a grey perlitic glass containing very numerous closely set and virtually identical white spherulites, each about 2 mm. in diameter. The spherulites are sharply delimited from the glass and the slightest touch is sufficient to free them, leaving behind clearly defined concavities in the perlite. The peculiar interest of these spherulites lies in the combination of three very unusual features, namely the strange individual pattern, the constancy with which all the spherulites adhere to that pattern, and the strongly marked orientation common to all of them.

The individual pattern is as distinctive as it is rare. Indeed, in my personal experience it is unique, yet this pattern is common to every one of the hundreds of individuals present. To make the specimen even more unusual, the spherulites are arranged in strictly parallel formation. They are as uniform as a carefully packed box of apples. Indeed, the fact that each spherulite has two dimples exactly opposite each other strengthens the simile. But for purposes of reference in the description that follows, it will be better to change the simile and compare each spherulite with a terrestrial globe in which the depressions occupy the polar positions, the different sections through the spherulite being referred to as equatorial, meridional, etc.

Viewed along the polar axis, the profile of each spherulite is almost circular, but viewed at right angles to the polar axis each spherulite has the silhouette of a rectangle with rounded corners. In thin section, they exhibit the following features. The equatorial sections

* For parts I. and II. of this series see Bryan (1940, 1954).



Meridional sections A, B, C and corresponding equatorial sections a, b, c showing three stages in the development of an apple-shaped spherulite.

show a central circular mass of radial spherulitic tissue about 1.5 mm. in diameter, around which is a concentric zone of later spherulitic growth about 0.3 mm. in width. The discontinuity in structure between the primary and secondary growth is clearly shown, especially as there is a tendency for rupture to occur along the junction during the preparation of microslides. In some cases it can be seen that the secondary zone itself consists of an inner and an outer ring.

Meridional sections are very different, each having a somewhat spool-like appearance. The central, primary development in such sections is again well-defined, but instead of being circular in section they are slightly elliptical with some polar flattening. In many slides, traces of a thin integument are seen to be attached to the central mass, only in the flattened polar areas, from which they extend outwards to form two projecting, umbrella-like membranes.

The secondary growth, too, in meridional sections, is divisible into two parts, an inner ring immediately around the primary spherulite and within the projecting membranes, and an outer region which not only completely covers the inner zone, but extends around the outer edges of the membranes to cover parts of them externally. As a result, only the polar areas of the central spherulite remain uncovered by secondary growths and thus form the dimples which especially characterise these spherulites.

Some individual spherulites show that small hemispherical growths have established themselves within the dimples, partially filling them. These exceptional cases provide the only notable departure from an otherwise striking uniformity.

2. Sequence of Events.

The observations outlined indicate the following sequence of events in the production of each of these very unusual spherulites:

1. Development of normal spherulite by radial growth.
2. Formation of enclosing integument on completion of growth.
3. Conversion of each sphere into a slightly oblate spheroid with, as a consequence, equatorial rupture of the integument and outward displacement of its two torn halves.
4. Supplementary spherulitic growth of first phase about the distal ends of the primary spherulitic fibres exposed by the rupture.
5. Supplementary spherulitic growth of second phase, beyond that of the first phase and around the projecting edges of the integument.
6. Formation of interstitial perlitic glass.

As the first and second items in this sequence are normal, there is every reason to believe that, if undisturbed, no further spherulitic crystallization would have occurred.

It would seem that the third event, although of critical importance, was accidental in character. The fact that all the spherulites were changed in the same way suggests that they were all affected by the same force at the same time. The fact too, that the spherulites, although all distorted, have the same orientation, indicates that the force was external in origin and unidirectional in character. This in turn indicates that the containing medium must have been sufficiently viscous to transmit a linear compression, possibly of short duration. The effect of this episode on each individual spherulite was similar to that produced on a spherical thin-shelled nut compressed by a pair of nutcrackers, involving as it did compression of the polar axis and complementary ring-tension about the equator. How the operating force was produced is not clear, but it may have been brought about by the suddenly imposed weight of a later flow on top of the stiff lava containing the spherulites.

The fourth event, which probably followed the third very closely, was the reintroduction of conditions favourable to spherulitic crystallization. This would be caused, in part at least, by some change in the interstitial material, the only possible source of supply for the new crystals. It is reasonable to suppose that the necessary change may have been brought about by a small rise in temperature. Such a rise may have been produced by heat derived from the cover of a new lava flow.

But the change in the interstitial mass, whatever its nature, was not sufficient to bring about a renewal of spherulitic growth, for no new centres of crystallization were initiated. Indeed, the conditions for renewed growth were most exclusive. Not only were they restricted to the immediate neighbourhood of the spherulites, but they were confined to the lower latitudes of these bodies.

The special environmental conditions which were peculiar to these favoured areas of renewed crystallization are worthy of especial attention.

1. The free distal ends of the original spherulitic fibres exposed by the rupture of the enclosing integument were in direct and immediate contact with the interstitial viscous lava.

2. These were the regions of least pressure when the spherulites underwent linear compression.

3. These were regions confined within the displaced integument as distinct from the polar regions.

The first of these conditions may well have been sufficient in itself to explain the resumption of spherulitic crystallization in the equatorial regions, but some added impetus may have been given by the second factor in terms of Soret's principle. That the third condition may also have been of some importance is suggested by the fact that this early phase of the supplementary growth did not extend beyond the margins of the partially detached integument, the two portions of which appear to have acted as protective shields, within which crystallization was able to proceed.

The fifth episode followed after a brief pause during which there may have been a slight rise in temperature. The fibres of this later supplementary spherulitic growth were, in turn, based upon the distal ends of those produced during the earlier phase. This extension spread outwards and polewards until it reached and turned the outer edges of the protective shields. It is noteworthy and significant that even after these had been turned there was no spherulitic growth based directly upon the integument, the nearest fibres lying lengthwise upon its surface and parallel to it.

This was the last event in which every spherulite took part, although some individuals show a still later supplementary growth within each polar depression.

The sixth event, with which the sequence concludes, was the final consolidation of the interstitial perlitic glass.

3. Conclusions.

If the observations recorded are accurate and the reasoning sound, certain conclusions of a more general character may be stated:

1. After spherulitic crystallization has ceased in a viscous lava, a sudden change in conditions may bring about a renewal of such growth.

2. The renewal of spherulitic crystallization may take place even if the lava is then so stiff as to be able to transmit unidirectional compression.

3. But under such extreme conditions the renewed growth is restricted to the exposed spherulitic tissue of an earlier generation.

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EXPLANATION OF PLATES.

PLATE I.

Figure 1.—Photograph of group of spherulites, showing polar depressions. x3.

Figure 2.—Photograph of part of specimen on which paper is based, viewed at right angles to the polar axes of the spherulites. x1.5.

PLATE II.

Figure 1.—Photograph of a typical individual, as viewed along polar axis. x20.

Figure 2.—Microphotograph of a nearly equatorial section of a similar individual. Crossed nicols. x20.

Figure 3.—Microphotograph of a meridional section of an individual spherulite. Crossed nicols. x20.

PLATE III.

Figure 1.—Microphotograph of meridional section of two closely appressed individuals. Crossed nicols. x20.

Figure 2.—Microphotograph of nearly equatorial section of two fused individuals. Crossed nicols. x24.

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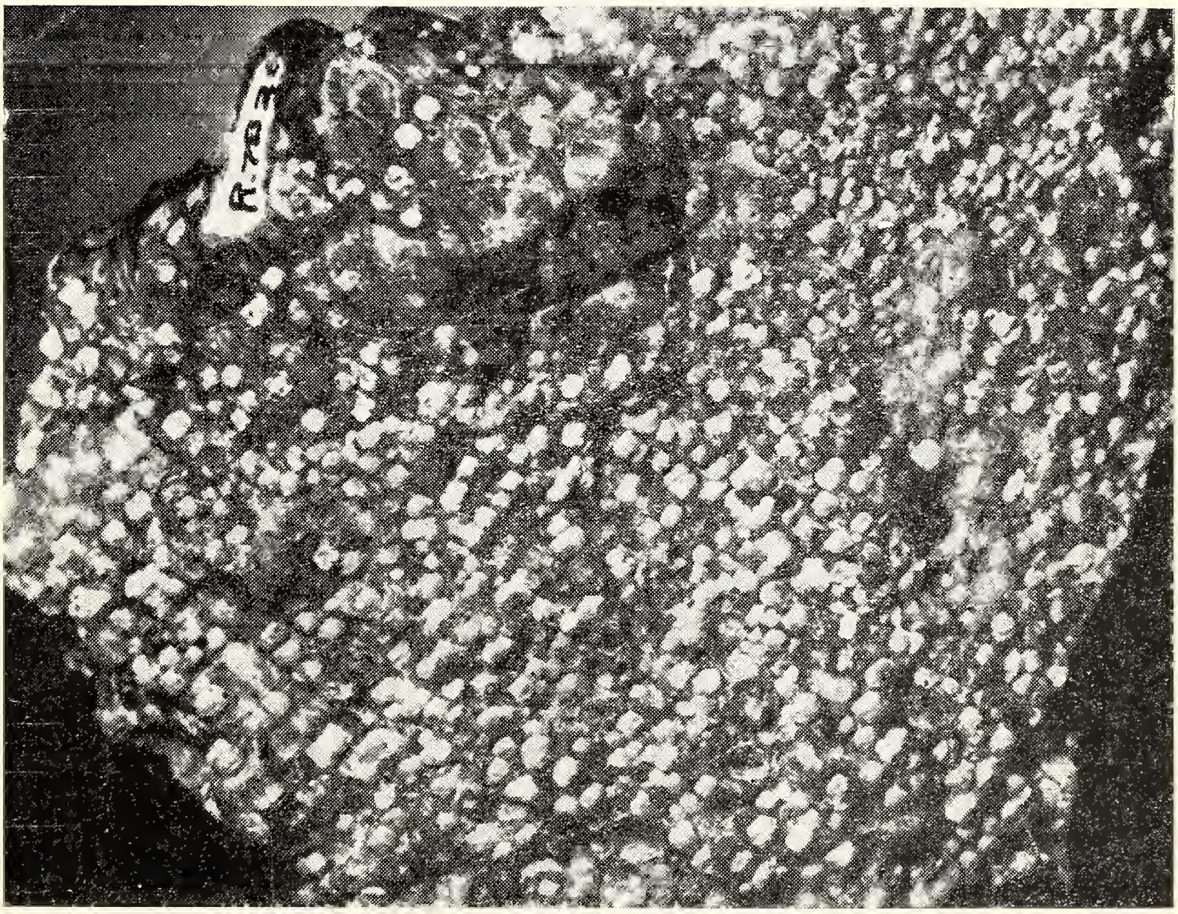

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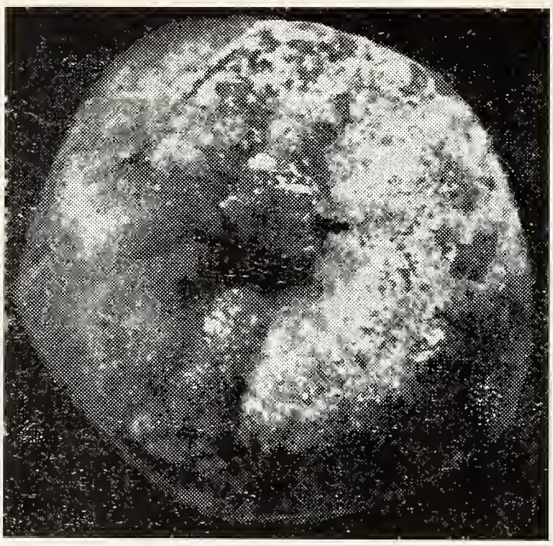

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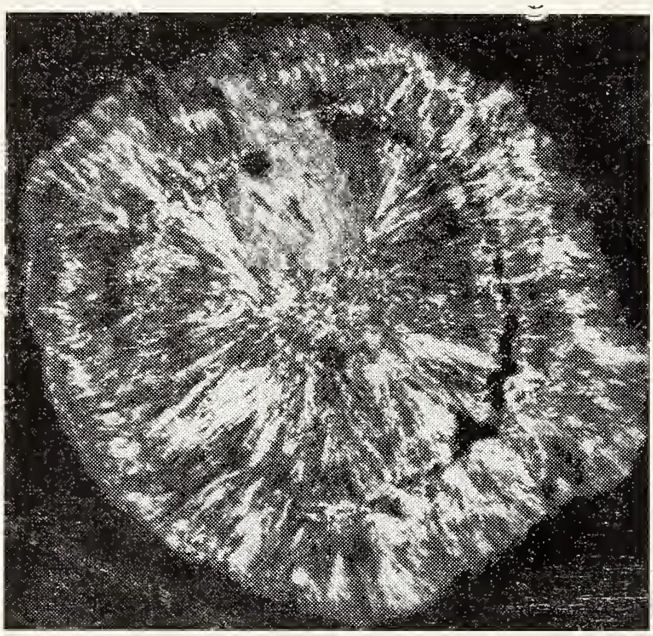

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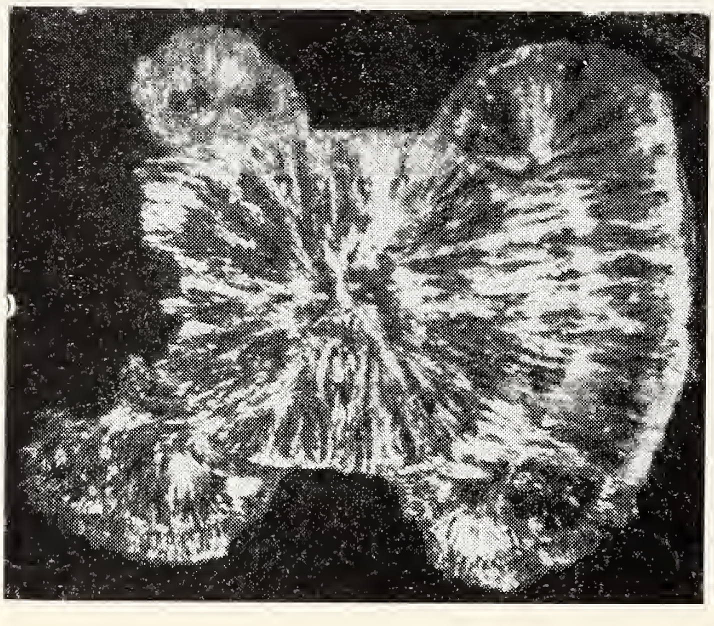

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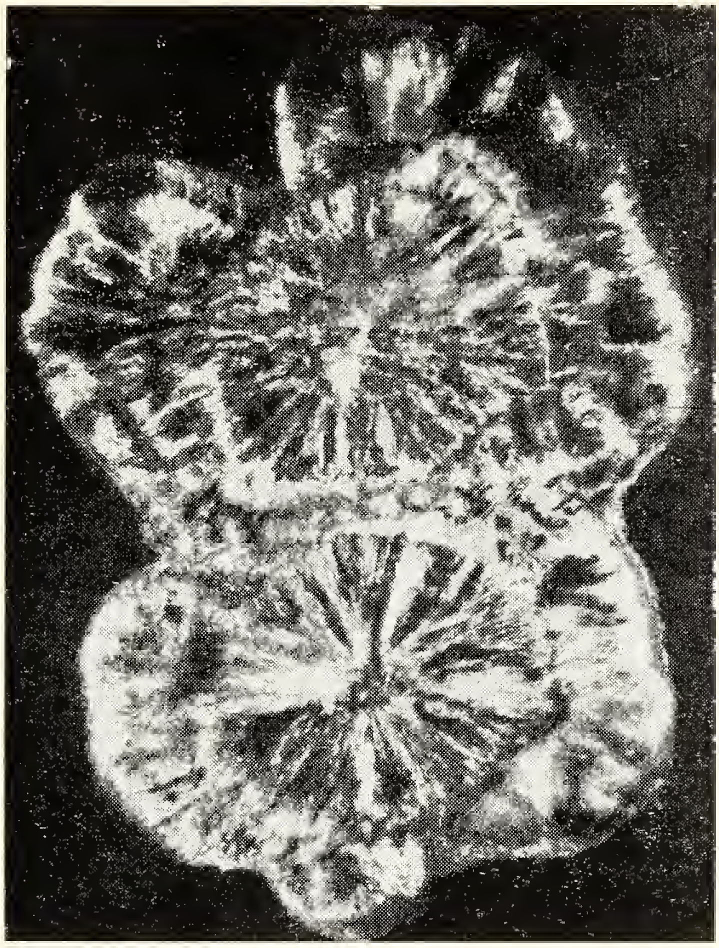

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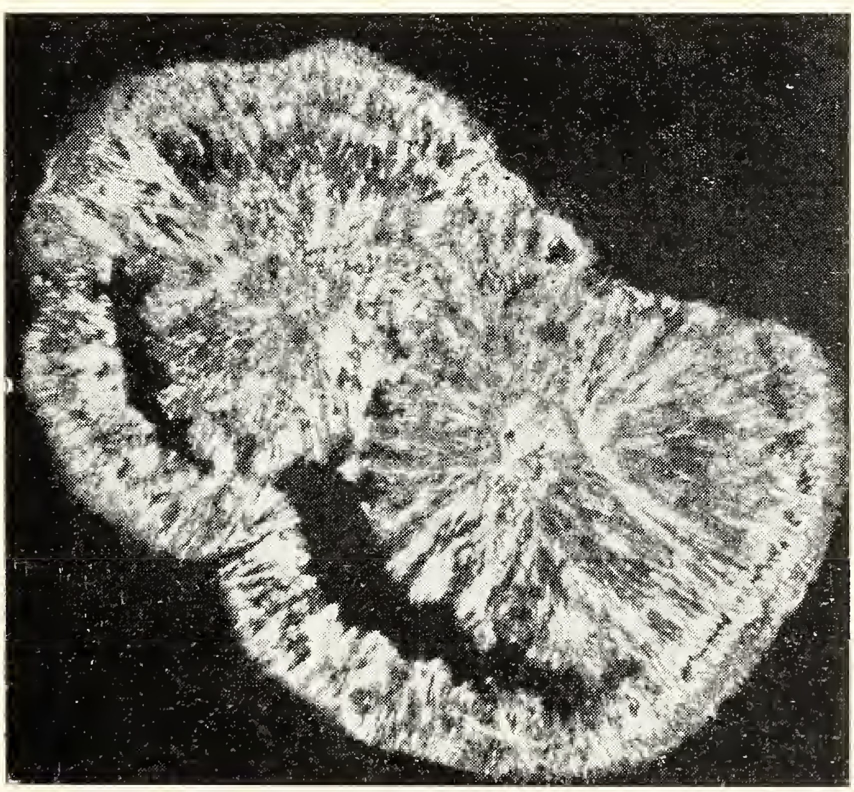

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Vol. LXVI., No. 4.

A PRELIMINARY ACCOUNT OF THE PETROLOGY OF THE CLONCURRY MINERAL FIELD.

By Germaine A. Joplin, Department of Geophysics, Australian National University, Canberra.

(With thirteen Text-figures.)

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CONTENTS.

I. INTRODUCTION.

The Cloncurry mineral field covers an area of approximately 35,000 square miles and occupies a region in north-west Queensland which includes the mining towns of Mount Isa on the west and Cloncurry on the east. A reconnaissance survey of the regional geology of this area is being undertaken by the Commonwealth Bureau of Mineral Resources, Geology and Geophysics, and in order not to anticipate work which will appear shortly in their Bulletin, the present paper is confined to a descriptive account of the main rock-types occurring within the area, and to the different metamorphic agencies affecting them. A brief summary of the tectonic and metamorphic history is included, and it is hoped that certain sections of the work may be studied later in greater detail.

The writer would like to thank Dr. N. H. Fisher, Chief Geologist of the Bureau, for allowing her to do this work in conjunction with the regional survey, and for making available camping and transport facilities. She also gratefully acknowledges the help of a number of the Bureau field officers, in particular that of Messrs. E. K. Carter and K. A. Townley. Mount Isa Mines Ltd. generously supplied information and a number of unpublished partial analyses, which are acknowledged with thanks. Apart from making several complete analyses, which are acknowledged elsewhere, Miss J. K. Burnett has determined several minor constituents in a number of analyses made by the writer and by B. E. Williams.

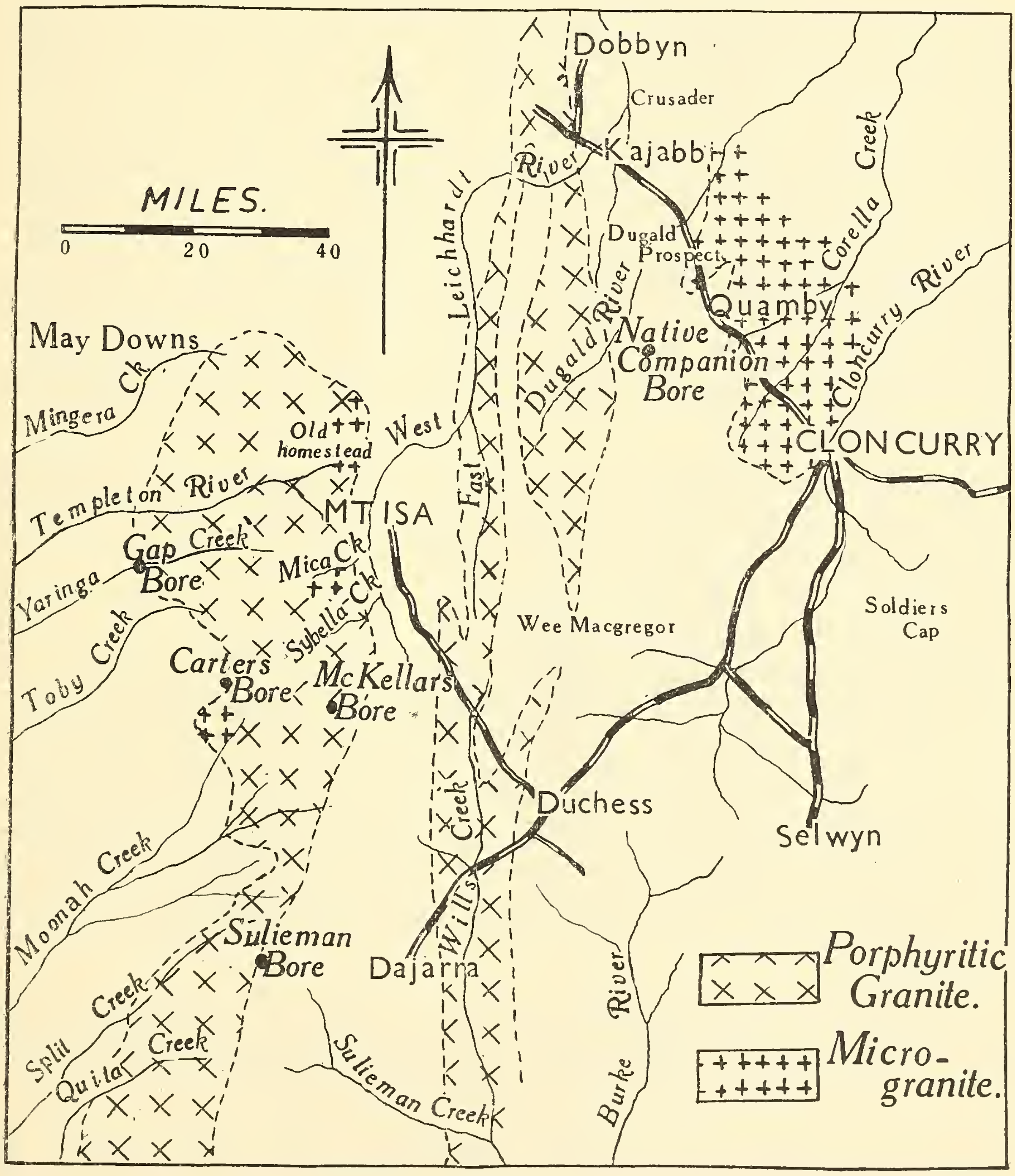
II. DEFINITIONS.

In an earlier paper (Joplin, 1952) it was pointed out that some confusion exists with regard to the use of some petrological terms, and that at times granitization appears to be used synonymously with contamination or with hybridization. In the present paper the term granitization is applied only when a small volume of magmatic fluid has converted a large volume of solid rock into a granite. If, on the other hand, a large quantity of liquid or semi-liquid magma appears to have assimilated a smaller volume of solid rock, then either the term hybridization or contamination is used. Following the original usages of these terms (Harker, 1904; Read, 1923) hybridization is reserved for the process when the incorporated material is of igneous origin, and contamination when it is of sedimentary origin.

In recent publications (Misch, 1949, a, b, c; Goodspeed, 1953) the terms synkinematic and static granitization are employed. Synkinematic granitization refers to a type which accompanies folding, is associated with regional metamorphism and takes place on a regional scale, whereas static granitization is not associated with folding and is not accompanied by regional metamorphism. Misch claims that this also takes place on a regional scale, but to the present writer his descriptions and Goodspeed's figures of replacement breccias, suggest a type of alteration which commonly occurs on the roof and walls of a batholith and passes inwards to a zone crowded with de-orientated xenoliths. This zone, according to the above definition, is a zone of either hybridization or contamination. If this interpretation of Misch's meaning is correct, then it would appear that static granitization is developed only locally about an igneous body, though in places it may appear to be of regional extent where a large body is only partly unroofed and this zone is exposed over a wide area. In the present paper the term static granitization is used in this sense.

III. AGE OF THE GRANITES.

Below it is shown that small masses of granite are associated with high grade rocks which are believed to be part of the basement upon which the Lower Proterozoic succession was laid down. Most of the granites, however, invade the Lower Proterozoic rocks, and among them two types may be recognized—a coarse porphyritic granite and a fairly even-grained microgranite. The porphyritic granite is the predominating type west of the Dugald River, and the microgranite to the east of the river. Small masses of the fine granite invade the coarse porphyritic type and it is obviously the younger, although chemical and mineralogical work suggest that the granites are of one age, the microgranite merely representing a later phase.



Text-fig. 1.

Locality map of Cloncurry mining field showing main areas of Proterozoic granite referred to in this paper. Boundaries are only approximate.

The areas occupied by these Proterozoic granites are roughly delineated in Figure 1. The map is based on previously published work, but some slight modifications have been made by the writer in certain areas with which she is familiar. It will serve as a locality map for the present paper, but it is hoped that soon it will be superseded by the publication of the maps in the Bureau memoir.

IV. TYPES OF METAMORPHISM.

As the country under consideration covers a very wide area, detailed mapping is impossible in a reconnaissance survey. Extensive collections have been made, however, and specimens pin-pointed on aerial-photographs on a scale of $1\frac{1}{3}''$ to a mile. In preparing this paper about 320 microslides have been examined in some detail.

Small areas of high-grade rocks believed to be parts of the basement, are briefly described, but this study is concerned mainly with the metamorphism of the Lower Proterozoic rocks, and with the granites that invade them. The Lower Proterozoic rocks west and south-west of Mount Isa attain a metamorphism no higher than the biotite-zone of regional metamorphism, and many of them are in the chlorite-zone. In these low-grades the rocks are mainly psammites, pelites and basalts. On the eastern margin of the batholith west of Mount Isa, however, these rocks are heavily greisenized and it is difficult to say what zone they may have attained before pneumatolysis, though there is nothing to indicate a high-grade. Near Soldiers Cap, garnet, cyanite and staurolite schists occur in a pelitic sequence and on the Dugald River, about 125 miles north-east of Mount Isa, pelites contain sillimanite together with cyanite.

The area has been heavily faulted and Bureau officers have shown that the major faults are pre-granite in age. Retrograde effects caused by faulting are, therefore, superimposed upon regionally metamorphosed but not upon contact altered rocks.

Many of the unstressed granites are surrounded by aureoles of contact metamorphism and effects may be thermal, hydrothermal or pneumatolytic. The last also occurs on the margin of the stressed granite west of Mount Isa where the rocks are greisenized and where tourmaline, fluorite and topaz have been introduced. In the exogenous contact-zones where the original rocks were basalts and impure limestones, pyroxene and calc-silicate hornfelses occur, and cordierite and quartz-mica hornfelses where pelite and arkoses are affected. On the Leichhardt River, a sequence of acid lavas have been recrystallized and some of these, together with arkoses west of Mount Isa, have suffered a static granitization.

As indicated by Edwards and Baker (1954) scapolitization has occurred in rocks of appropriate composition, though they do not attribute the origin of the scapolite-forming solutions to the granite.

In the Lower Proterozoic succession these five types of metamorphism have affected four groups of rocks which are described in some detail below. For convenience, the metamorphism of these is summarized in Table I.

TABLE I.

Type of Metamorphism.	Aluminous and Siliceous Rocks.	Calcareous Rocks.	Acid Lavas.	Basic Lavas and Intrusives.
Regional Metamorphism	Chlorite– and Quartz-chlorite Schists	Chloritic Marbles	..	Uralitized Gabbro, Blastophitic Dolerite
	Biotite Schists ..	..	Dacites with hornblende pseudomorphed by biotite	Amphibolites and Hornblende-biotite Schists
	Garnet–, Cyanite– and Staurolite–Schists (with or without Andalusite)	..	..	..
	Cyanite – Schists with Sillimanite	Pyroxene–, Hornblende-pyroxene, and Biotite-scapolite Granulites	..	Pyroxene– and Hornblende–pyroxene Schists and Gneisses
Retrograde (Dislocation) Metamorphism	Silicified Slates with cataclastic structures	Tremolite Rock	Lavas with cataclastic structures	Chlorite-amphibolites and Chlorite–Schists
Thermal (Contact) Metamorphism	Cordierite quartz–Hornfelses, and Quartz – muscovite Rocks (Arkose)	Diopside-plagioclase Hornfelses (Class 7) Diopside – garnet–plagioclase Hornfelses (Class 8)	Recrystallized Rhyolites and Dacites	Pyroxene Hornfelses and Recrystallized Dolerites
Metasomatism	Greisenization with addition of tourmaline, fluorite and topaz	Scapolitization*	..	Formation of Biotitites
Magmatic Addition	Static granitization of Arkoses	..	Static granitization of Rhyolites and Dacites	Acidification of basic xenoliths

* The metasomatism of the aluminous and calcareous rocks is not necessarily contemporaneous.

V. THE OLDER METAMORPHIC COMPLEX.

A few yards west of the MountIsa-Dajarra Road, at a distance of 6½ miles north-west of the Sulieman Bore, a knotted, greenish rock is overlain by flat-dipping sandy schists, which show little alteration except at their immediate contact with the porphyritic granite further west. The knotted rocks are cordierite-andalusite-sillimanite gneisses and their origin and stratigraphical position are matters for speculation. In these rocks, xenoblasts of cordierite measure up to 1 cm., and contain numerous inclusions of biotite, quartz, tourmaline, rutile and zircon. The zircons are surrounded by a characteristic yellow halo and the cordierite is altered to sericite and pinite along cracks and cleavage planes. In places subidioblastic columnar crystals (0·6 mm.) of andalusite are intergrown with cordierite. Biotite is pale reddish brown and shows alteration to sillimanite. Brown idioblasts of rutile are numerous and relatively large, and small crystals of a black metallic mineral have not yet been identified.

In the vicinity of Gap Bore another metamorphic unconformity appears. The Lower Proterozoic rocks nearby are in a low grade of regional metamorphism and are invaded by the porphyritic granite, the foliation of which is approximately north-south. Near Yaringa Creek, however, small areas of schist, granitized schist and granite are exposed and these show a marked east-west directional structure. The granite is very variable, some outcrops being even-grained and others slightly porphyritic. Phenocrysts are scarce and very sporadic in their distribution even within a single outcrop. The granite is intimately associated with psammopelites, and *lit-par-lit* injection is present in places. Xenoliths are not common, but in places almost completely granitized shadowy fragments may contain porphyroblasts of felspar up to 25 mm. in length. An aplitic type of granite also occurs, and it is intersected by small dykes and veins of pegmatite. One such vein appears to be folded with the granite. When much contaminated by schist, the granite is dark in colour and in hand specimen resembles a mica diorite.

Some of the related schists are very coarse and almost gneissic with bands of biotite and muscovite alternating with bands rich in cordierite and quartz; others contain augen up to 1.5 mm. which consist of a mosaic of quartz and biotite, and these are set in a finer mosaic of quartz, muscovite and biotite with a false cleavage. Some rocks show seams of iron ores transgressing the schistosity and suggesting an original banding.

Most of the granites contain subidiomorphic phenocrysts of plagioclase (about 4 mm.) with inclusions of microcline, and in some, small phenocrysts of microcline also occur. The groundmass consists of a mosaic of quartz, felspar and biotite and the biotite may be intergrown with iron ore and contain inclusions of apatite. One granite contains a little pinitized cordierite, and a yellow isotropic material which is mantled by epidote, may be allanite.

Further to the north-east, at the head of Mica Creek, a coarse cordierite schist has been greisenized at the margin of the later porphyritic granite. It contains large (6 mm.) ellipsoids of cordierite, crowded with inclusions in a granoblastic mosaic of quartz, biotite, muscovite, and a little sillimanite is present. This area needs further investigation, but it seems likely that this rock antedates the general metamorphism of the Lower Proterozoic succession.

At 13 miles south-east of the old May Downs homestead, a small area of coarse knotted schist appears to occur with others of lower grade, but this also needs further investigation in the field. The rock contains large (12 mm.) porphyroblasts of cordierite thickly studded with inclusions of biotite, sillimanite, muscovite and minute grains of iron ore. These are surrounded by coarser flakes of biotite which are intergrown with a granoblastic groundmass of quartz, biotite and muscovite with bands of fibrous sillimanite.

About 4 miles south-west of Rifle Creek Dam, Mr. E. K. Carter found a well-rounded granite-like boulder in a matrix of schistose rhyolite. This rock contains large porphyroblasts of microcline and plagioclase in a granoblastic base of quartz, biotite, muscovite, sphene and iron ore. The felspars are heavily sericitized, and within some of them large flakes of muscovite are developed. Carbonates are also present. The rock is threaded with quartz veins which are probably related to the rhyolite that engulfed the boulder.

This boulder indicates that granitized rocks were present in the vicinity of Rifle Creek before the outpouring of the rhyolites, and since the main granites of the region post-date the acid lavas, there is reason for assuming an older granite basement. Furthermore, the presence of arkoses west of Mount Isa points to the proximity of an earlier granite, and the metamorphic unconformity and difference in the direction of the foliation also suggest that these small exposures are part of that basement.

Nevertheless, some of these granites are not unlike some of the later porphyritic hybrids described below. Careful comparison, however, will show that there are some differences. First, the younger granite is characteristically porphyritic, whilst granite considered to be older has very rare and sporadic phenocrysts. Second, the smaller quantity of microcline is strikingly different in the older granite compared with the non-porphyritic younger type. Third, the older granite contains far more muscovite than either of the younger types, and, whilst fluorite is ubiquitous in the younger granites, it has not been noted in the older.

VI. THE LOWER PROTEROZOIC SUCCESSION.

1. The Country Rocks and their Metamorphism.

(*a*) Aluminous and Siliceous Rocks.

Pelites, psammopelites, psammites and psammites with a tuffaceous matrix, as well as arkoses are included in this section. Although aluminous and siliceous sediments are not prominent in the Lower Proterozoic succession in this region, they are found in thin seams on many horizons interbedded with the calcareous types and with the acid and basic lavas. As indicated above it has not been possible to draw zones of regional metamorphism, but it can be broadly stated that on the west most of the rocks are either in the chlorite-zone or come just on to the edge of the biotite-zone where there is a development of green mica. Near the Dugald Prospect, carbonaceous rocks are in the biotite-zone. West of the Wee Macgregor Mine in the Ballara Area, and locally in the Soldiers Cap Area, garnet-, staurolite-, and cyanite-bearing schists are developed, but as some of these contain andalusite they are not typical of the garnet, staurolite and cyanite-zones. In the Dugald River Area, cyanite schists contain sillimanite.

About ¾ mile east of Mount Isa a white slate consists of fine grains of quartz and minute flakes of sericite and chlorite with larger patches of leucoxene. A slight schistosity cuts across the sedimentary bands at an angle of about 30°. About 6 miles south of Mount Isa on the Dajarra Road a fine tuffaceous psammite, containing quartz, felspar, chlorite and carbonaceous material, is associated with a basalt (Fig. 7) which has suffered only slight alteration.

Near the Native Bee Copper Mine, 13½ miles south of Mount Isa, fine slate or tuff shows small grains of quartz in a dense matrix of green biotite, and west of the shear-zone on Sybella Creek fine grained quartz-muscovite schists also contain a little green biotite. South of Carters Bore a screen of sediments in a low grade of regional metamorphism is adjacent to the porphyritic granite on the east, and to a small mass of microgranite crowded with sedimentary xenoliths, on the west. At the northern end of the screen a conglomerate contains large stretched pebbles of quartz and quartzite in a schistose matrix of chlorite and pale green mica, quartz and magnetite, the chlorite and mica occurring as streaks and lenses in a mosaic of fine quartz. Adjacent psammopelites contain small porphyroblasts of chlorite in a granoblastic base of quartz and orientated flakes of muscovite with a trace of biotite. Coarse bands and lenses have the same composition with the addition of a little iron ore. Tourmaline occurs sporadically in these rocks, and in some of them original clastic structures are preserved. About 1½ miles south of Carters Bore quartz-sericite schists occur. They are probably in the chlorite-zone, the development of chlorite possibly being inhibited by their composition.

Near the Dugald Prospect, 11 miles north-west of Quamby, the rocks are in the biotite-zone. They are finely banded schists consisting of quartz and brown biotite, with carbonaceous material marking the sedimentary banding. Other types, showing coarser, less carbonaceous bands, contain muscovite.

In parts of the Soldiers Cap area and in the Ballara area, west of Wee Macgregor Mine, some rather anomalous high-grade schists occur. They are described very briefly here as it is hoped that more detailed work can be done after another field season. A number contain staurolite porphyroblasts, up to 10 mm. in length (Fig. 2A). Idioblastic garnets ranging in size from 0.25 mm. to 1.5 mm. also occur, and these with the staurolite are present in a lepidoblastic and granoblastic base of quartz, reddish brown biotite, muscovite and carbonaceous material.

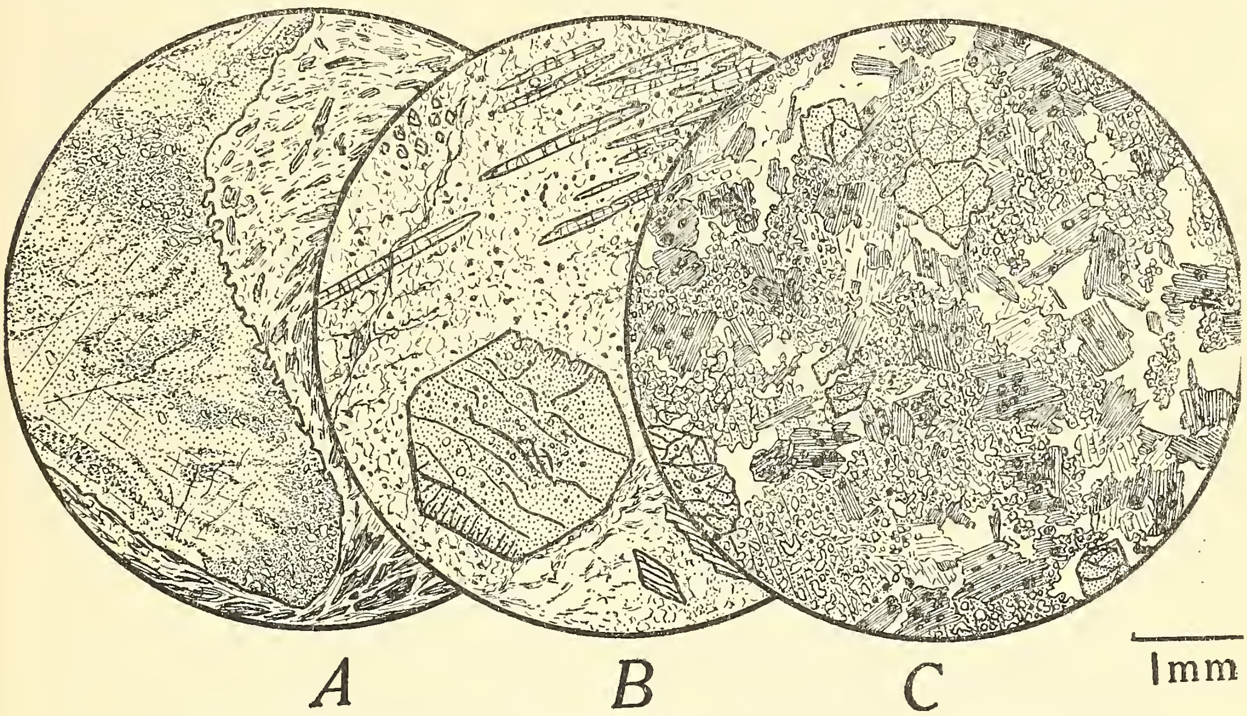
Garnetiferous schists containing radiating bunches of bladed crystals of cyanite also occur in some parts of the district. Both garnet and cyanite are in a fine granoblastic base of quartz, white mica, chlorite and a little iron ore (Fig. 2B).

Other rocks contain large poikiloblastic porphyroblasts of andalusite up to 25 mm. in length. These contain small (0.2 mm.) idioblasts of garnet and are surrounded by a fairly coarse (0.75 mm.) fringe of muscovite which passes out into a finer lepidoblastic base of muscovite and biotite with porphyroblasts (1 mm.) of garnet (Fig. 2C).

In the Dugald River area rare pelites and psammites are associated with calcsilicates. The pelites consist of subidioblastic crystals of cyanite in a coarse (1.5-2 mm.) intergrowth of biotite and muscovite.

Sillimanite forms mats of small needles enclosed in muscovite, and a little iron ore is also present. Associated psammites are coarse biotite-muscovite-quartz-schists. Fluorite and apatite are present in some of these rocks.

With regard to dislocation metamorphism, very few of the aluminous and siliceous rocks have been examined in the shear-zones. A psammite from the Soldiers Cap area shows a relict clastic structure with granulated, banded and undulose patches of quartz surrounded by a fine mylonite-like aggregate of quartz and white mica, and a coarse schist from south of Mount Isa shows the development of plumose mica in a silicified quartz-muscovite-biotite-schist. The quartz shows strain.



Text-fig. 2.

A. Staurolite schist from west of Wee Macgregor Mine, showing part of a twinned porphyroblast with peripheral embayments and patches of inclusions. The base consists of quartz, biotite and muscovite and shows bending around the end of the porphyroblast.

B. Cyanite-garnet schist from Soldiers Cap area showing porphyroblast of garnet and bundle of cyanite crystals in a quartz-mica base. A transverse section of a cyanite bundle is shown on the top left.

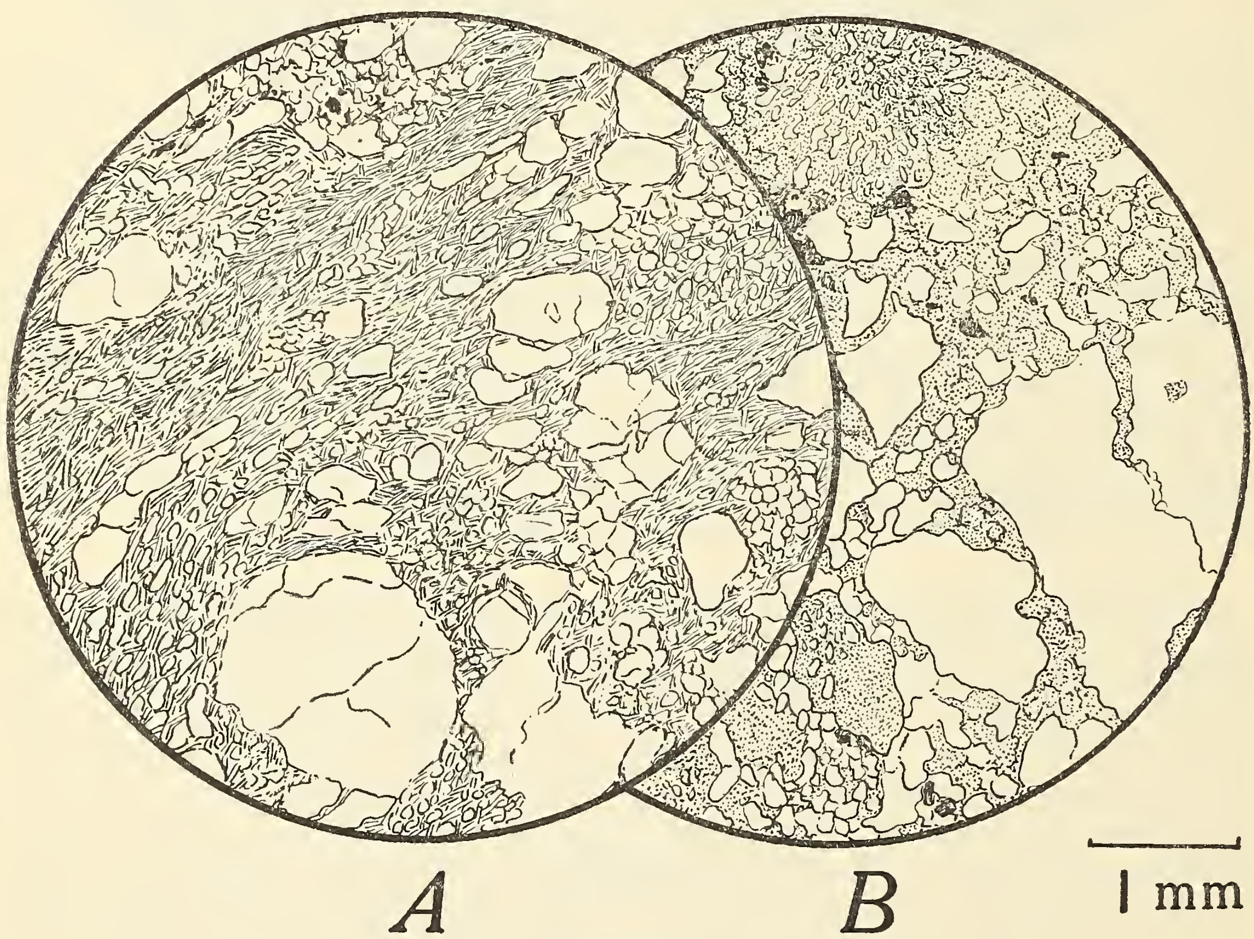
C. Andalusite-garnet schist showing irregular parches of optically continuous andalusite, porphyroblasts of garnet and tabular flakes of biotite with inclusion of zircon. Muscovite and quartz are also present.

Coming now to contact metamorphism, contact-altered pelites are recorded, but psammites are abundant and mostly interbedded with basalts. These are common about 5 to 7 miles east of the old May Downs Homestead. A slightly calcareous psammite consists of a fine granular mosaic of quartz, felspar, epidote, green biotite, iron ore, and rare small, columnar porphyroblasts of colourless amphibole. Some of the psammites are banded with seams of fine and very fine quartz, felspar and biotite. Small porphyroblasts of chlorite occur within the seams and are normal to the sedimentary banding. Other psammites contain muscovite. Although these rocks are completely recrystallized, they have not attained a very high grade of thermal metamorphism.

Granitized psammites are locally developed on the margin of the western batholith, and on Waverley Creek, about 50 miles south-west of Mount Isa a banded siliceous type contains microcline, which appears to have been derived from the granite. A fragment of fractured garnet, partly altered to muscovite, is present in this rock. In many places in the Dugald River area psammites also are granitized. These contain irregular porphyroblasts of microcline (3 mm.) and of quartz (1 mm.) in a fine lepidoblastic base of biotite, quartz, felspar and a trace of sphene. Other rather similar rocks contain apatite, chlorite and muscovite.

On the north-eastern margin of the batholith, west of Mt. Isa the rocks have suffered pneumatolytic alteration and many of the pelites are now represented by a micaceous lepidoblastic schist. The biotite flakes measure about 2 mm., and the muscovite crystals which are slightly larger may cross cut the biotite bands. Fluorite is present in many of these rocks. It commonly occurs in very small grains and may partly replace felspar. Tourmaline is fairly common in small crystals, but schorls may develop in places, and on the back road through May Downs a micaceous schist contains crystals of tourmaline up to 150 mm. in length and 65 mm. in diameter. Near Sybella Creek the greisenized schists contain a little topaz.

The porphyritic granite has invaded arkoses on Mingera Creek, about 28 miles west-north-west of Mount Isa, and exposures of contact-altered arkose may be seen on the back road between the old and new May Downs Homesteads, near Beetle Creek. Arkoses also occur as roof-pendants or screens associated with granite 25 miles north-west of Mount Isa. These masses are both contact-altered and granitized. The rock least altered by addition appears to be an arkose with rounded grains



Text-fig. 3.

A. Contact altered arkose showing recrystallized grains of quartz in a matrix of muscovite and quartz.

B. Granitized arkose showing large grains of quartz in a felspar-quartz matrix. The quartz and felspar are graphically intergrown at the top of the figure.

of milky quartz in a stony base, and a later stage shows the development of large rectangular porphyroblasts of felspar in the arkose. This mass is invaded by the granite and in most places the contact with arkose is sharp.

Contact-altered arkoses show a relict clastic structure with rounded areas of granulated quartz up to about 3 mm. in diameter in a base of fine granular quartz and mats of extremely small flakes of muscovite which may sweep round the larger masses of quartz (Fig. 3A). Some types contain a little biotite and iron ore. Granitized arkoses contain large porphyroblasts of microcline and a good deal of felspar in the groundmass, much of which is graphically intergrown with quartz. The rounded clastic grains of quartz may still be recognized, but otherwise the rock resembles a granite (Fig. 3B).

(b) Calcareous and Calcsilicate Rocks.

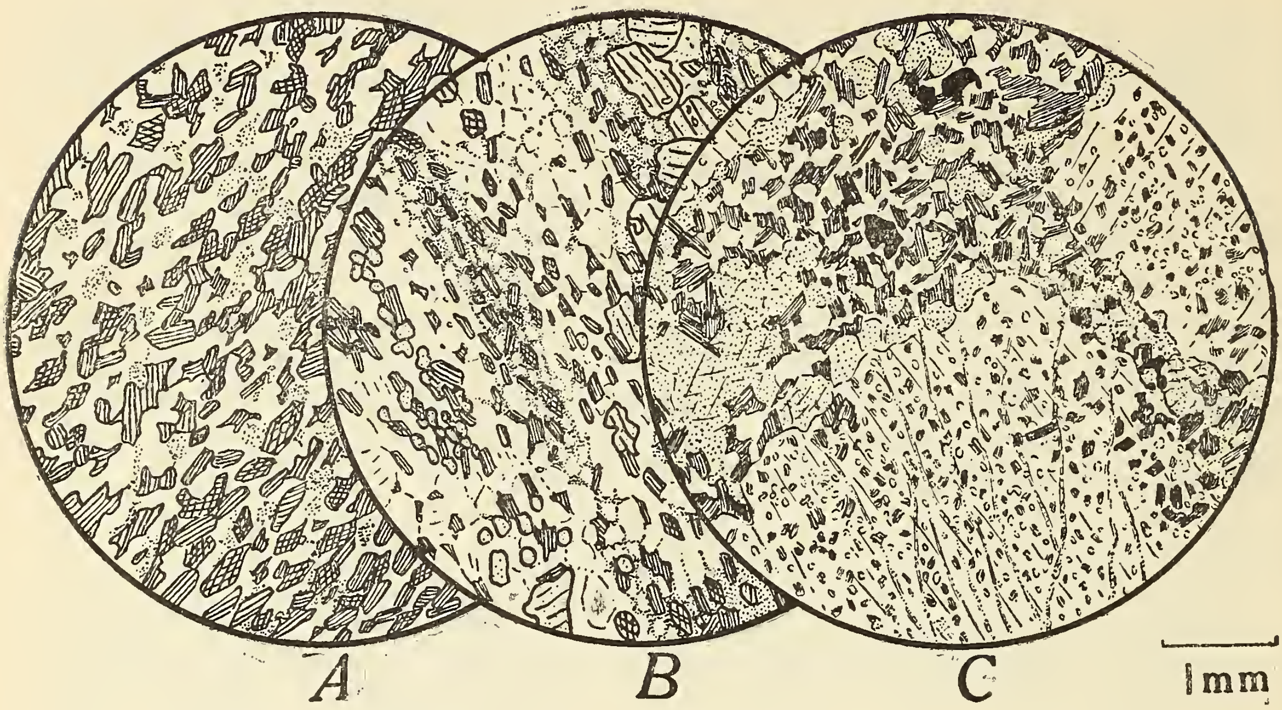
The Mount Isa series of Shepherd (1953) occurs at Mount Isa and forms a meridional outcrop which, according to Shepherd, extends at least 200 miles north and 120 miles south of the town. On the west it is invaded by granite and on the east underlain by basalts. The sequence consists of shales, calcareous and dolomitic shales and some thin beds of limestone and dolomite.

A calcareous sequence with interbedded normal shales in the Duchess area has been described by Edwards and Baker (1954), who also described scapolitized calcareous rocks in the Trekelano and Dugald River areas. This sequence was formerly referred to as the Argylla Series (Honman, 1937; Shepherd, 1953), and Edwards and Baker have suggested the possibility of its being the more highly metamorphosed equivalent of the Mount Isa shale. On petrological grounds, the present writer concurs with this suggestion, and for convenience the calcareous and dolomitic members of both sequences are described together. Although most of the types mentioned below have been fully described by Edwards and Baker (1954), the present summary is included in this regional study for the sake of completeness.

The banded calcareous and dolomitic shales at Mount Isa are in a low grade of metamorphism. An interbedded marble consists of calcite and chlorite and interbedded pelites are in the chlorite-zone. Near the Dugald Prospect, 11 miles north-west of Quamby, very similar types occur and interbedded pelites reveal that they are in the biotite-zone.

In hand specimens the rocks near Mt. Isa appear to have suffered very little alteration apart from local silicification, but under the microscope the arrangement of minute flakes of sericite, chlorite and carbonate minerals indicate a slight schistosity. Dense masses of carbon make difficult the identification of minerals in some of these fine-grained rocks. These low-grade rocks from both localities appear to have escaped scapolitization.

From the Dugald River area, Edwards and Baker described scapolite-pyroxene-granulites, scapolite-marbles, scapolite-biotite-schists and scapolite-albite-hornblende schists. In hand specimens these rocks are very similar to hornfelses from the Duchess area described below. On Cleanskin Creek, a tributary of the Dugald, these granulitic rocks are interbedded with pelites which contain cyanite and sillimanite, and in this case their texture is the result of high-grade regional metamorphism and not contact metamorphism. This is substantiated by the co-existence of calcite and quartz in the same rock.



Text-fig. 4.

A. Hornblende-plagioclase schist showing lineation of hornblende and incipient scapolitization of felspar.

B. Banded granulite showing seams of pyroxene-scapolite-quartz and hornblende-plagioclase.

C. Spotted granulite showing large poikiloblastic porphyroblasts of scapolite in a base of quartz, biotite, calcite and iron ore.

Hornblende-plagioclase rocks show a marked foliation, and when much hornblende is present, they are schists rather than granulites (Fig. 4A). A number of these rocks have been examined from the Mount Burstall area, and it is difficult to decide whether they are impure dolomites or basic igneous intercalations. Plagioclase ranges from andesine to albite and is commonly much sericitized. Incipient scapolitization of the felspar is also present. Near Mount Burstall, scapolite-pyroxene-quartz assemblages, with or without hornblende, alternate with hornblende-plagioclase assemblages (Fig. 4B) and this compositional banding parallels a slight lineation. Some of these rocks contain a little bright orange mica suggestive of titaniferous phlogopite (Prider, 1939).

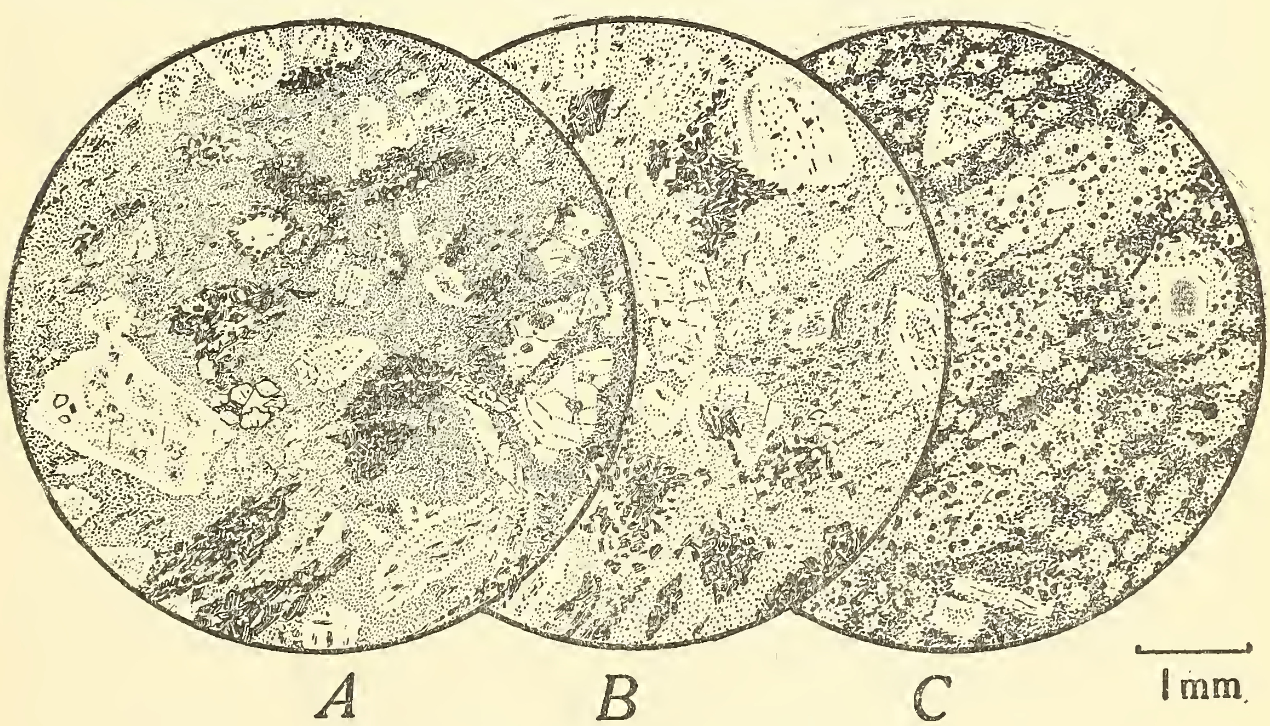
Edwards and Baker also described scapolite-biotite schists in the Dugald River area, and similar types are very widespread between Native Companion Bore and the Dugald River, 14 miles west-south-west of Quamby. In hand specimens, they are spotted grey granulites forming narrow seams that alternate with non-spotted types. The spots are porphyroblasts of scapolite that measure up to 5 mm. (Fig. 4C). They have a marked sieve-structure. Edwards and Baker found that biotite tended to be rejected by the scapolite, but at this locality inclusions of biotitie are numerous, though they are lighter in colour than that of the granoblastic base, and there may be some chemical difference. Quartz and felspar also occur as inclusions in the scapolite and the base contains quartz, biotite, calcite and iron ores; fluorite has been noted in some specimens.

With regard to the dislocation metamorphism, sheared types have not been recorded among the high-grade rocks, but in the lower grades there has been much deposition of silica and dolomites have been converted into tremolite-calcite rocks.

Contact metamorphism is evidenced in places. Near Duchess, the calcareous sequence consists of dense banded granular rocks with light and dark grey and green seams ranging in width from a few to over a hundred millimetres. These rocks are adjacent to granite and appear to be typical hornfelses. The most common type is a diopside-plagioclase assemblage, but some rocks also contain a little brown lime-iron garnet. According to Goldschmidt (1911) these would belong to the hornfels classes 7 and 8. Diopside-hornblende-plagioclase and hornblende-plagioclase assemblages also occur, and these possibly represent either Class 6 hornfelses formed under conditions of wet contact metamorphism (Joplin, 1935) or intercalations of a basic igneous rock. From this area, Edwards and Baker have described scapolite-bearing marbles and scapolite-pyroxene- and scapolite-hornblende-pyroxene-granulites which appear to represent the scapolitized representatives of the above mentioned hornfelses. Edwards and Baker also have described the leached equivalents of these rocks in the Duchess and Dugald River areas, and have shown that certain red rocks have been formed by the removal of magnesia, lime and iron oxides with the re-precipitation of some of the iron oxide as haemetite.

(*c*) Acid Lavas.

A sequence of rhyolites and dacites, with some toscanites, andesites, basalts and tuffs has suffered several different types of metamorphism. As there is a marked similarity in the mineralogical composition of this suite of rocks, except for the basalts described below, they are dealt with together in this section and only differences noted.



Text-fig. 5—Regionally altered Acid Lavas.

A. Dacite with corroded phenocrysts of quartz, tabular phenocrysts of plagioclase and micaceous pseudomorphs of hornblende in a fine groundmass. A slight schistosity is apparent.

B. Rhyolite showing quartz, albite and microcline phenocrysts with patches of criss-cross biotite in a fine crystalline groundmass. The arrangement of mica indicates a slight schistosity.

C. Recrystallized (?) spherulitic obsidian.

All the rocks are highly porphyritic with quartz and felspar phenocrysts and criss-cross patches of biotite, which, in the more basic types, are probably pseudomorphing original hornblende phenocrysts. It seems likely that the regionally altered rocks are mainly in the biotite zone, though there are no interbedded pelites to identify the zone. Quartz phenocrysts are idiomorphic and two sizes of crystals (3 mm. to 0.6 mm.) are commonly present in the same specimen. In the more basic types, quartz phenocrysts are less numerous and smaller (1.5 mm.). In all types they are highly corroded and crowded with pseudo-inclusions (Fig. 5A and Figs. 6A and B). Undulose extinction is common and minute inclusions of mica and chlorite follow curved lines within the crystal suggesting recrystallization along lines of conchoidal fracture.

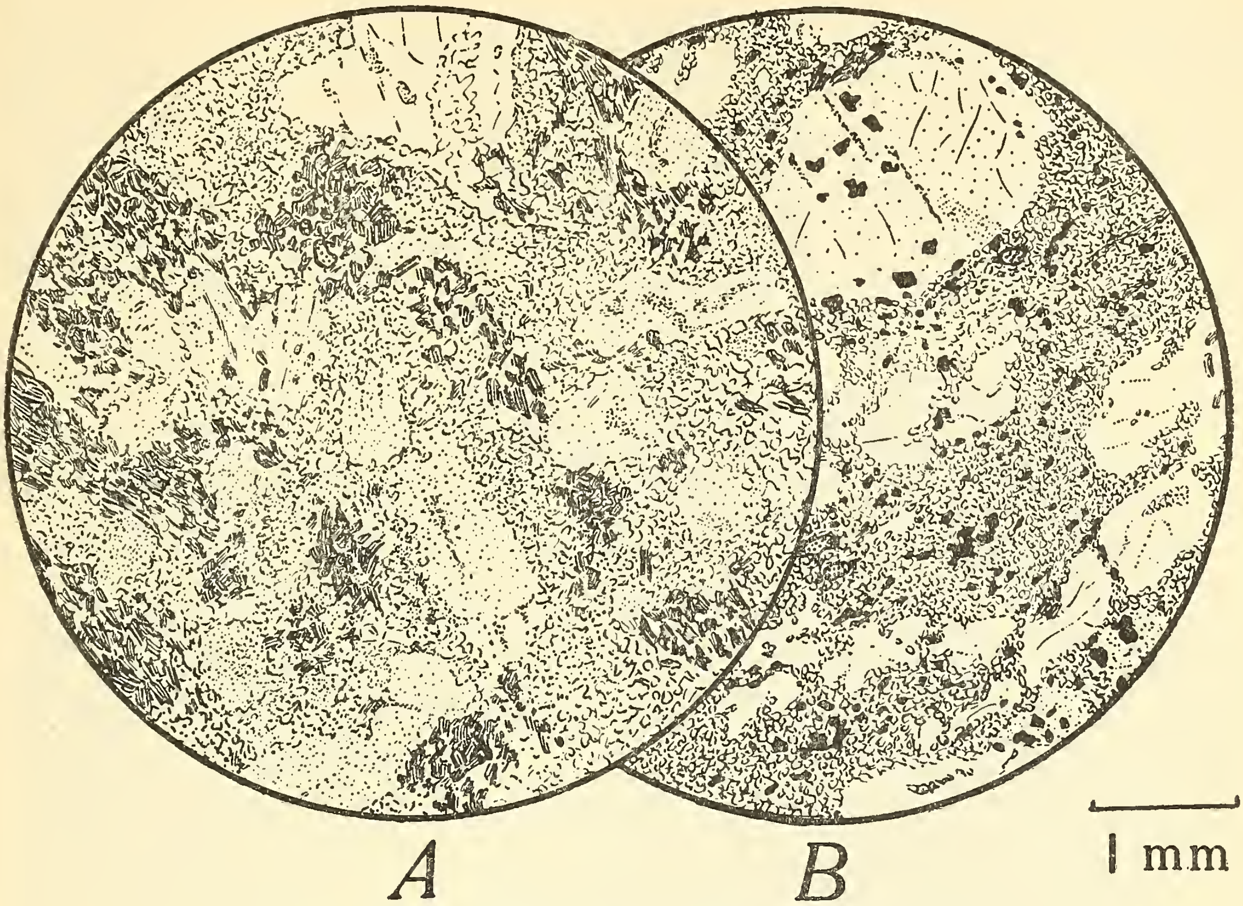
Tabular phenocrysts (1-3 mm.) of plagioclase range from albite in the rhyolites to andesine in the more basic rocks. The albite may show a peculiar twinning similar to the chequer albite of the albitites. It is commonly altered to sericite and the more basic types are heavily saussuritized with granular epidote, clinozoisite, calcite and albite among the flakes of sericite. In some dacites, calcite forms elongate grains replacing felspar. In some more basic types there is a glomeroporphyritic grouping of the plagioclase. One of the rhyolites shows a vein of microcline cutting plagioclase phenocrysts.

Rhyolites contain tabular phenocrysts of microcline (3 mm.) and smaller phenocrysts (about 0.75 mm.) occur in the toscanites. Simple Carlsbad twinning may be present in addition to the typical gridiron grating. Microcline may be albitized, and cut by veins of albite.

Dacites and more basic types contain biotite in small (0.1-0.01 mm.) criss-cross flakes which form clusters measuring up to about 3 mm. in length and appear to be pseudomorphs after hornblende. These are commonly associated with granular sphene, epidote and calcite. Iron ores are rare or absent in these aggregates. The pleochroism of the biotite is from yellow to chocolate or from greenish-yellow to deep brownish-green. One dacite contains xenoliths of a coarser, slightly more basic, type, and there is an interesting reaction-ring of granular magnetite about a xenocryst of pyrite.

The groundmass of these rocks consist of a fine mosaic of quartz, felspar and mica. Staining with sodium cobaltinitrite has revealed a little potash felspar in the more acid types. The mica is mostly sericite, but some types contain a little greenish-brown biotite. Accessories are apatite and iron ores. A vein of fluorite has been noted in one of the rhyolites. Several of the rhyolites contain narrow bands of a fine granular rock with a peculiar cellular structure. Small phenocrysts of quartz occur amongst the cellular material, and it is suggested that the bands may represent recrystallized spherulitic obsidians (Fig. 5C).

The effects of dislocation metamorphism are not readily apparent, and sheared rocks differ from the regionally altered only in that the sericite of the groundmass shows a marked lineation and phenocrysts may be orientated in the direction of the schistosity. This may be accentuated by the development of an augen structure and a coarser crystallization of the groundmass at each end of the phenocrysts. Quartz phenocrysts show undulose extinction, strain banding or complete granulation; the more basic types of plagioclase may be broken down into granular calcite and epidote; and hornblende phenocrysts are represented by trails of biotite in the direction of the schistosity.



Text-fig. 6—Thermally altered Acid Lavas.

A. Dacite showing completely recrystallized groundmass with nibbled margins of phenocrysts.

B. Recrystallized rhyolite showing the same features.

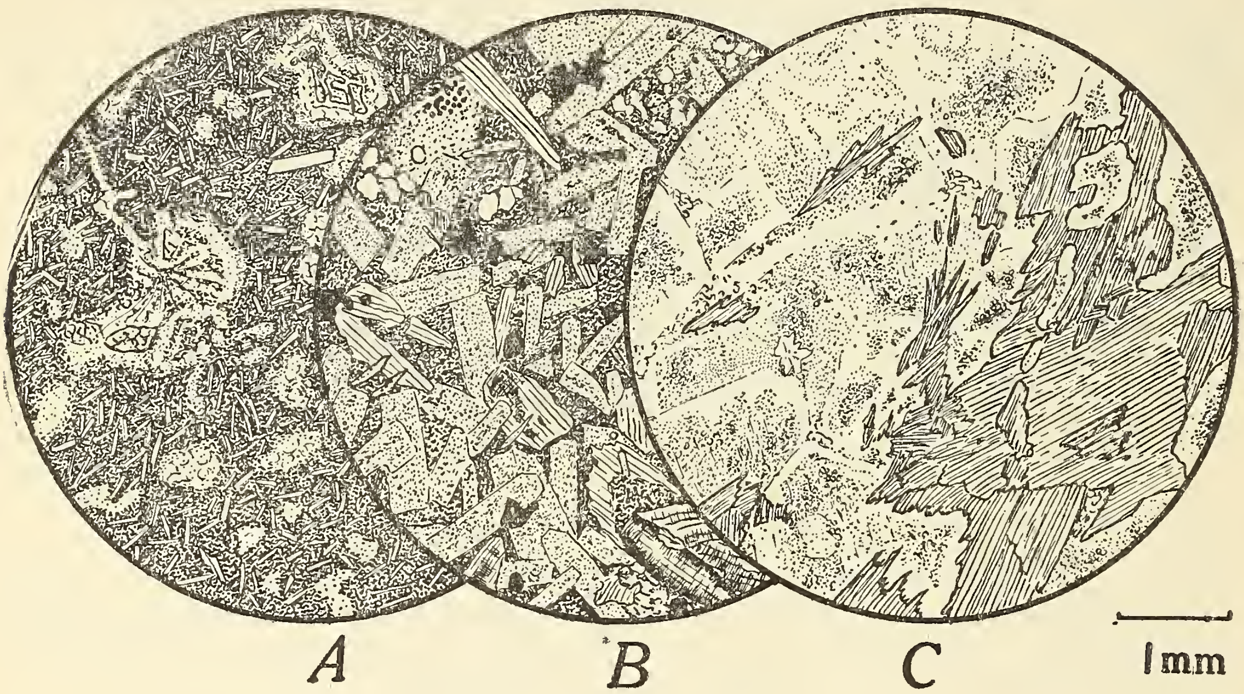
Contact metamorphism is evidenced by a coarser granoblastic groundmass against which the phenocrysts show a characteristically nibbled margin (Figs. 6A and B). Quartz phenocrysts are completely granulated, and in one of the rhyolites, microcline phenocrysts show a zone of quartz blebs with an outer rim of clear untwinned felspar.

On the Leichhardt River this volcanic sequence forms the roof of a batholith which is only partly exposed. Most of the rocks are recrystallized as described above, but in places quartz and microcline phenocrysts show very indefinite outlines and may in fact be porphyroblasts that have grown as the result of static granitization. A fine grained, banded microcline granite appears to represent the complete granitization of a banded rhyolite.

(*d*) Basic Lavas and Intrusives.

A thick succession of basic lavas interbedded with quartzite will be described in the bulletin to be issued shortly by the Commonwealth Bureau of Mineral Resources. In the present paper they are discussed, with the basic intrusives, as a group of basic rocks that have suffered different types of metamorphism. Most of the lavas are the Spring Creek basalts of Shepherd (1953).

Basic dyke swarms invade the acid lavas between Mount Isa and Cloncurry in the region of the East and West Leichhardt Rivers and small bodies of gabbro occur in the noses of a number of folds in the Mount Isa and Cloncurry areas. In most instances original structures have been obliterated, and except for their field occurrence, it would be difficult to identify specimens as either intrusive or extrusive. Three examples of the least altered rocks are shown in Fig. 7. The basalt occurs on the Dajarra Road 6 miles south of Mount Isa. It consists of a plexus of small laths of plagioclase surrounded by chloritic material in which are embedded a dense mass of small grains of magnetite. It seems likely that the base is a recrystallized glass since iron is commonly concentrated in the residual liquid. This rock also contains small irregular patches of carbonates, some with a centre of epidote and these no doubt represent former amygdules which may have originally contained either these minerals or lime zeolites.



Text-fig. 7.

A. Partially altered hypohaline amygdaloidal basalt showing small laths of plagioclase in a fine recrystallized base rich in magnetite. Amygdules are filled with granular calcite and epidote. Dajarra Road, 6 miles south of Mount Isa.

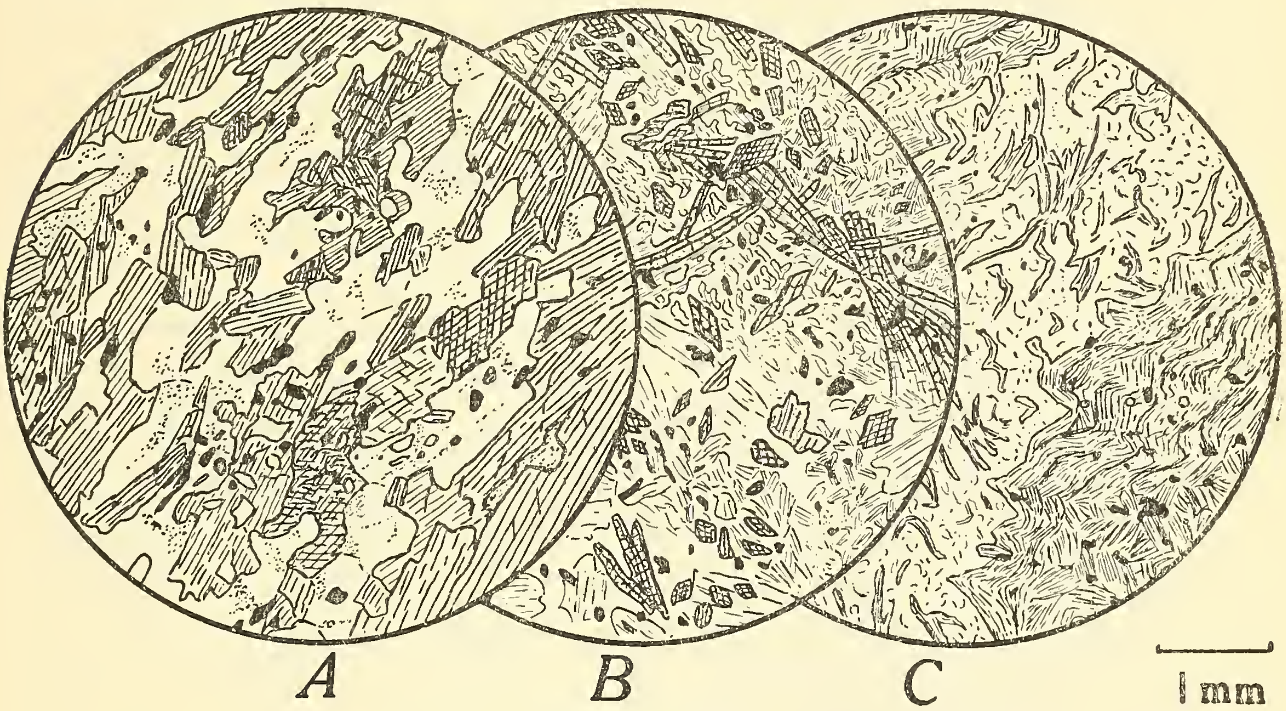
B. Slightly altered dolerite with blastophitic and blastointergranular structure. Interstices are filled with chlorite and magnetite, and small patches of quartz may be partly released quartz. Plagioclase is heavily sericitized and stained by haematite, and most of the augite is altered to green hornblende. Partly altered augite shows a sahlite parting (bottom of figure).

C. Altered gabbro showing saussuritized tabular plagioclase and aggregates of uralitic hornblende. Cloncurry Road, 7 miles east of Mt. Isa.

The least altered of the dolerites occurs to the south of Mount Isa. Its structure is blastophitic and blasto-intersertal. Plagioclase laths measure up to 3 mm. in length and are much altered and stained with haematite. Relict crystals of augite measure up to 2 mm. and are partly enveloped by green hornblende, and small independent crystals of hornblende occur with chlorite in the intersticies where needles of apatite and grains of magnetite are common. Small grains of released quartz are also interstitial, and in places a fine graphic intergrowth of quartz and felspar is present in the mesostasis.

The gabbro (Fig. 7C) occurs on the Cloncurry Road 7 miles east of Mount Isa. The structure is blastogabbroid. Original augite is completely replaced by uralitic hornblende which forms masses of several grains about 6 mm. in diameter. Small flakes of phlogopite are associated with the amphibole. Andesine is subidiomorphic tabular (about 4 mm.) and is heavily saussuritized with some incipient scapolitization.

The regionally metamorphosed basic rocks are very widespread and show a great variation in grainsize. The main constituents are hornblende and plagioclase (Fig. 8A). Hornblende crystals may range in size from 0.2 mm. to 10 mm.; it is a strongly coloured variety with X = light olive green, Y = olive green and Z = dark bluish-green and it shows a well marked parallelism in the direction of the schistosity. Plagioclase is andesine and is commonly sericitized and not well twinned. It forms xenoblasts, sometimes interlocking with quartz, and occurs intergrown with hornblende. In some rocks the felspar occurs in augen or narrow bands and the rock is a hornblende gneiss rather than a schist. Iron ores, usually ilmenite, sphene and apatite are present in all these rocks. Some banded quartz-rich varieties may have been tuffs, and one such rock is exceptionally rich in epidote. Segregations of quartz in some rocks suggest silicification.



Text-fig. 8.

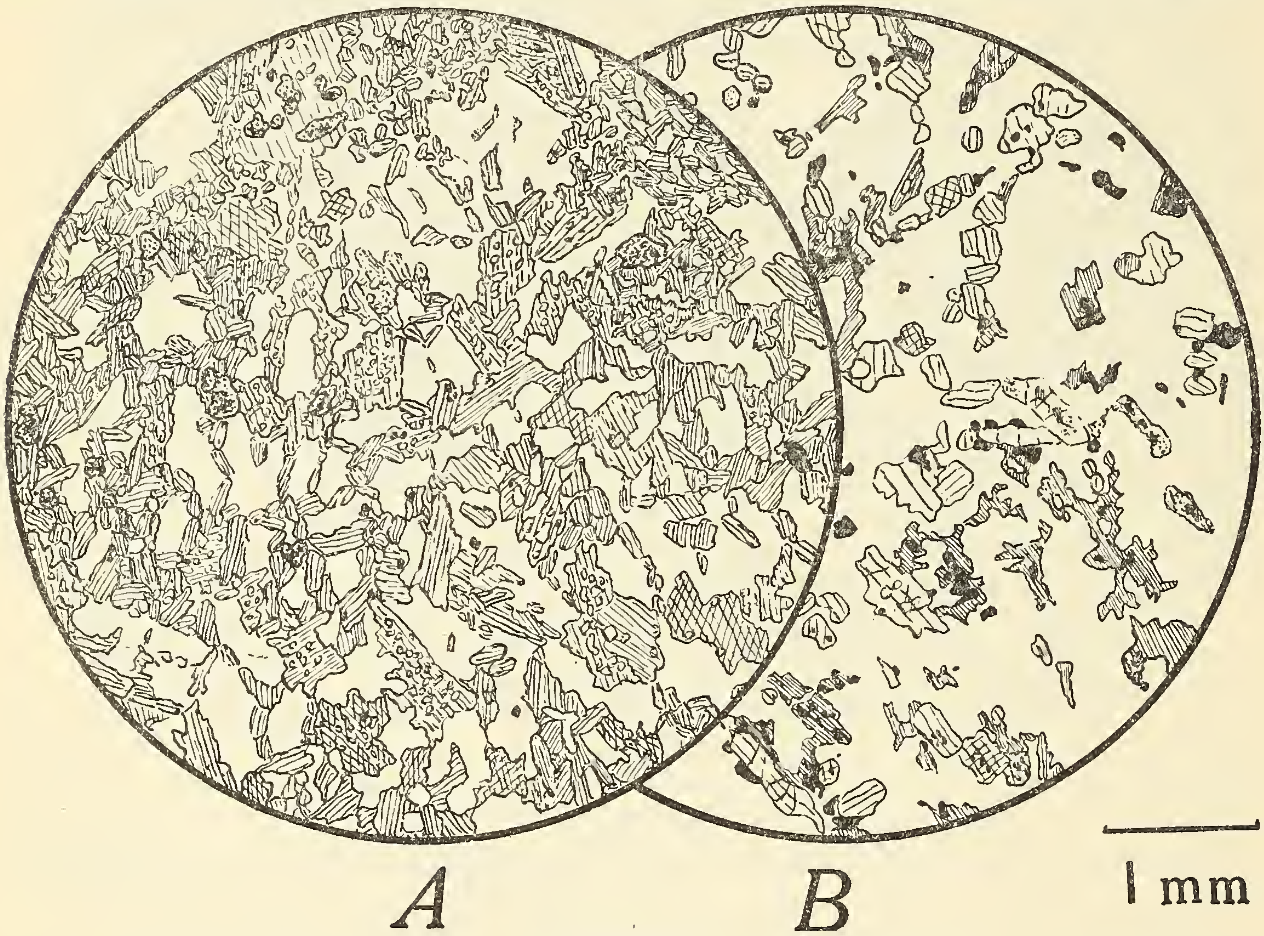
A. Coarse hornblende schist or hornblende-plagioclase gneiss, near McKellar's Bore.

B. Sheared basic rock showing sheaf-like group of pale, columnar amphibole in a base of chlorite, plagioclase, quartz, iron ore and sphene. Gap near Sybella Creek.

C. Strongly sheared basic rock segregation into chlorite-rich and plagioclase-rich bands. Accessory minerals are iron ore and apatite. A well marked plication is developed in the chloritic bands and is only just discernible in the chlorite-poor. Gap near Sybella Creek.

Dislocation metamorphism is evidenced in the shear zones by a more marked schistosity and the schists may be strongly plicated. The least sheared types contain elongated columnar crystals or needles of pale green amphibole, which in one rock appears to be anthophyllite. If abundant, the slender crystals are arranged in sheaf-like or stellate groups (Fig. 8B), and when little amphibole occurs single crystals pierce chlorite or plagioclase. Chlorite is not abundant in types rich in amphibole, and the two minerals are in a roughly inverse relationship. In the most sheared types, chlorite has developed to the exclusion of amphibole. Some rocks contain a little light golden yellow biotite and flakes of both chlorite and mica follow a well marked plication (Fig. 8C.) In the less sheared types these minerals occur in a fine mosaic of plagioclase with accessory quartz, epidote, sphene and iron ore. In the more sheared types felspar and quartz are segregated into lenses or bands and the plication is only just discernible across them (Fig. 8C.) In a few rocks small patches of plagioclase fringed and pierced by needles of amphibole suggest an original phenocryst. Plagioclase commonly shows alteration to clinozoisite and to carbonates.

Thermally altered basic rocks occur as remnants on partly unroofed granites about 12 miles north-west of Mount Isa and on the Leichhardt River to the east. West of Mount Isa they occur as flows interbedded with quartzites, and on the Leichhardt they occur as dykes cutting the acid lavas. The least altered of the dyke rocks have a blastophitic structure and consist mainly of plagioclase and hornblende with accessory sphene, epidote and iron ore. Plagioclase laths are slightly



Text-fig. 9.

A. Dolerite showing early stage of contact metamorphism. A blastophitic structure is still present, but crystalloblastic structures are indicated by the granoblastic intergrowth of plagioclase and hornblende (top right, and bottom) and by early poikiloblastic hornblende. Dyke on Leichhardt.

B. Thermally altered basalt showing pyroxene and clear felspar and biotite enveloping iron ores. A rought parallelism of these minerals indicates an earlier schistosity. East of old homestead, May Downs.

''nibbled'', and a faint greyish-brown clouding is indicative of the first stages of contact metamorphism (Macgregor, 1931; Joplin, 1933). Green hornblende forms small columnar crystals with numerous felspar and quartz inclusions indicating an incipient poikiloblastic structure, and in places small xenoblasts of amphibole are intergrown with felspar (Fig. 9A).

In the railway triangle north of the open cut at Duchess. Edwards and Baker (1954) reported basic rocks containing olivine, and though the present writer has not encountered this mineral, specimens from this locality reveal that the rocks are in a low-grade of contact metamorphism comparable to the type figured and described above. Some rocks contain a little scapolite.

In a higher grade of thermal metamorphism, rocks east of Mount Isa consist of a granoblastic mosaic of felspar and pyroxene with some fox-red biotite, iron ore and quartz. Small remnants of amphibole, heavily charged with magnetite dust appear to be passing over to pyroxene. Augite forms stout columnar crystals, which show a rough parallelism and possibly preserve the earlier alignment imposed by regional metamorphism. Biotite tends to envelope and fringe grains of iron ore (Fig. 9B). Plagioclase is extremely clear with a smoky grey clouding in the centre of the crystal, its composition is oligoclase or andesine and the somewhat acid nature suggests that it has contributed lime to the pyroxene. Some of the dykes on the Leichhardt are also in this higher grade. Table II. shows that there is some uniformity in the composition of these rocks despite the different types of metamorphism they have suffered.

TABLE II.

——	I.	II.	III.	IV.	V.	VI.	VII.
SiO_2	49·56	48·66	48·8	47·5	48·9	49·1	49·2
Al_2O_3	16·53	17·36	15·1	18·0	12·6	15·3	15·2
Fe_2O_3	1·25	1·96	16·2	15·4	17·7	19·3	14·0
FeO	10·69	8·88					
MgO	7·21	6·88	6·9	5·6	8·4	5·1	7·3
CaO	10·67	9·13	10·1	10·5	8·9	8·4	11·4
Na_2O	3·35	3·28	..	..	..	..	..
K_2O	0·89	1·29	..	..	..	..	..
H_2O +	0·22	0·58	2·2	2·5	2·5	2·0	1·8
H_2O –	0·05	0·06					
TiO_2	n.d.	1·46	..	..	..	..	..
P_2O_5	0·21	n.d.	..	..	..	..	..
MnO	0·06	0·11	..	..	..	..	..
	100·69	99·65					
Sp. Gr.	3·065	3·001	..	..	..	..	..

I. Thermally altered Basalt $3\frac{1}{2}$ miles east of Old Homestead, May Downs, west of Mount Isa. Anal. B. E. Williams.

II. Xenolith in Microgranite. $5\frac{1}{2}$ miles east of Old Homestead, May Downs. Anal. G. A. Joplin.

III. Mean of Four Partial analyses of Greenstones. Spring Creek, Mount Isa By courtesy of Mount Isa Mines Ltd.

IV.-VII. Partial analyses of Greenstones from Spring Creek. By courtesy of Mount Isa Mines Ltd.

Biotitites occur sporadically on the margin of the porphyritic granite west of Mount Isa, and as they are associated with greisenized sediments they are believed to represent basic rocks that have been altered by pneumatolysis. Certain basic rocks have suffered acidification and static granitization, and though most of them are discussed with the granites that they have hybridized, it is fitting that the least altered types should be noted here. Some of the contact altered basic dykes on the Leichhardt show acidification and closely resemble a rock occurring on the eastern bank of the West Leichhardt which appears to be a roof-pendant. This mass is a dense, black granulite threaded with veins of epidote. Porphyroblasts (2 mm.) of plagioclase and ragged grains of green hornblende, in decussate groups, are associated with iron ores, epidote and apatite. Apatite occurs in relatively large crystals.

These minerals are surrounded by a fine granoblastic mosaic of quartz, plagioclase and hornblende. Similar rocks occur near the head of Mica Creek, and on May Downs, 13 miles north-west of Mount Isa. A little biotite is present in some and its origin may be due either to magmatic addition or to an earlier metamorphism.

2. The Intrusive Rocks.

(a) Albitites and Soda Granites.

These rocks form small sporadic outcrops in the Soldiers Cap and Dugald River areas as well as west of Mount Isa, and it is probable that detailed mapping would reveal others. The field relations are obscure, though in most places they are close to and are possibly intrusive into the microgranites described below. On the other hand, some masses appear to be related to the earlier basic rocks, and again several are found along fault zones.

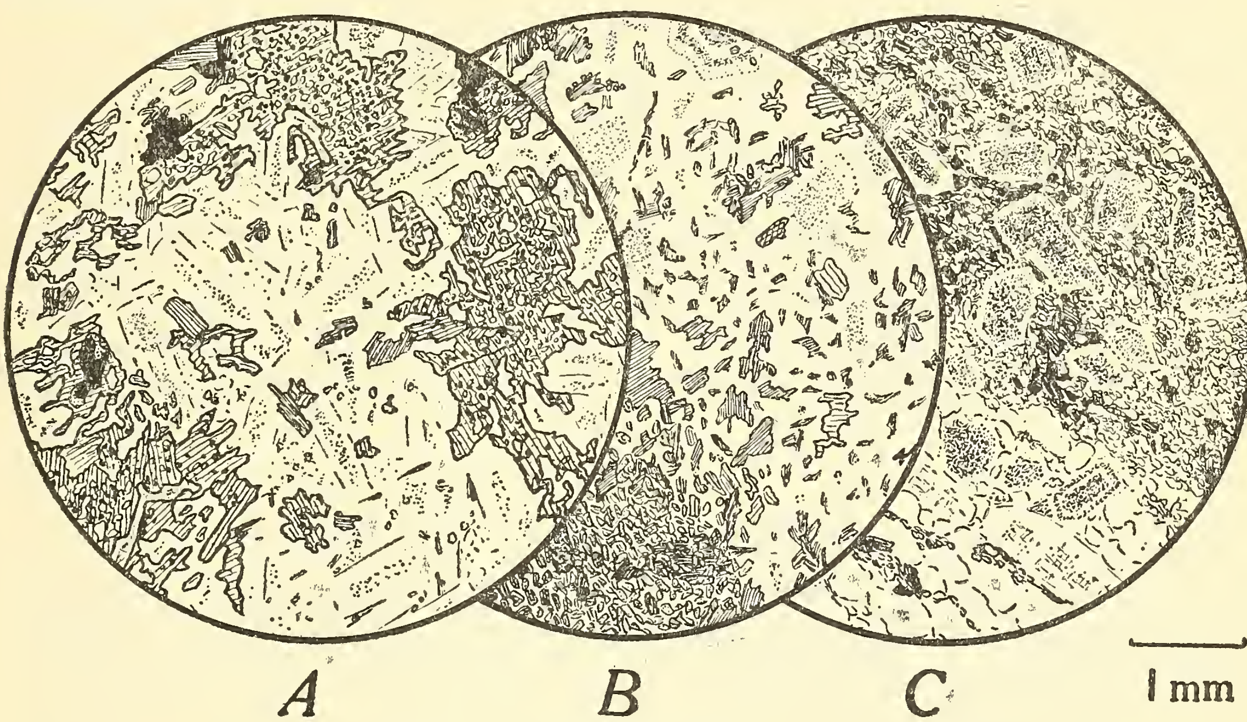
In the Soldiers Cap area they range from albitites with only a trace of quartz to albite granites in which quartz is a prominent mineral. The average grain size ranges from 0.75 mm. to 1.5 mm., but much finer grains of quartz and felspar may be interstitial and suggest a mortar structure. Two miles north-east and 5 miles east of the old homestead on May Downs, the albitites are slightly coarser and grains of albite may measure 3.5 mm. in diameter though finer material is also present. Albite occurs in irregular grains or in subidiomorphic tabular crystals, and drop-like inclusions of quartz may be present. It normally shows a well marked albite twinning, but a peculiar lamination reminiscent of the twinning of microcline is present in some grains. It appears however to be confined to one direction and may be the chequer albite referred to by Browne (1920). A little pale biotite or chlorite occurs in most rocks, and iron ores and sphene are constant accessories. Small grains of tourmaline and a few comparatively large grains of a metallic mineral occur in the albitites from Mount Isa. The metallic mineral was examined in polished section by Mr. W. Roberts of the Bureau of Mineral Resources and identified as ilmenite.

Hybrids.

Near the Volga Mine a fine, white aplitic type containing a little amphibole, cuts a basic rock. East of the old May Downs Homestead the albitite appears to have been injected along a pre-granite fault-zone in which basic rocks have been converted to chlorite schists and chlorite-biotite schists. The shattered basic schists occur as very numerous small xenoliths in the albitite which, on weathered surfaces, has a peculiar nodular appearance. The igneous rock has been slightly hybridized and now consists of a coarse mosaic of albite with scattered irregular flakes of chlorite, pale green mica, and small granules of sphene and iron ore. Some of the chlorite and mica is pyrogenic, but some appear to be mechanically incorporated and to have retained the original plications imposed on these minerals in the fault-zone. An analysis of this hybrid, freed as far as possible from mechanically derived material, is shown in Table III, column II.

A little further east, a dense dark medium-grained rock contains large rounded crystals of hornblende. In hand specimen it resembles a basic diorite, but under the microscope it is obviously a hybrid consisting of a mixture of mechanically incorporated basic material in a coarse base of chemically basified material. In places a slight blastophitic structure is noted and it seems likely that the incorporated rock was not sheared before the incoming of the albitite. The portion which remained solid shows a well marked crystalloblastic structure and consists of poikloblasts of green hornblende, heavily charged with iron ores, in a base of plagioclase, quartz and biotite (Fig. 10A). The plagioclase is andesine and occurs in laths or tabular crystals ranging in size from 1 to 3 mm. as well as in small irregular grains. A slight mottling of some of the larger crystals evidences reaction (Joplin, 1933).

The high soda content of these hybrids shows their parentage with the albitite rather than with the microgranite. In most cases, this is not obvious in the hand specimen, and in the field, the relationship is not clear owing to the fact that the albitite and microgranite are closely associated.



Text-fig. 10.

A. Albitite-basalt hybrid showing large poikilitic porphyroblasts of hornblende in a base of plagioclase laths, quartz and biotite.

B. Basic xenolith in microgranite with adjacent hybrid. The xenolith consists of a plexus of small hornblende crystals and a few large poikiloblasts of biotite with a trace of felspar and quartz. The hybrid is composed of plagioclase, biotite, hornblende, quartz and a trace of sphene.

C. Sedimentary xenolith consisting of porphyroblasts of turbid plagioclase in a fine granoblastic groundmass of quartz, biotite and felspar. The hybridized granite in the lower part of the figure consists of turbid plagioclase, microcline, biotite and abundant quartz.

The basic lavas in this area are interbedded with quartzites, and in places the basified albitite has shattered the sedimentary seams and mechanically incorporated them. In the field, rounded xenoliths of quartzite occur in the diorite-like rocks and under the microscope some specimens show small (0.3 mm.) highly sutured grains of quartz and larger (0.7 mm.) ragged flakes of biotite associated with iron ore in a fine base of plagioclase laths, interstitial quartz and a little epidote and hornblende. Some rocks appear to be albitites with strewn fragments of undigested basic igneous and sedimentary material, others appear to be basified albitites with mechanically incorporated quartzites. It thus seems evident that the basic material is the more susceptible to chemical assimilation.

TABLE III.

——	I.	II.	III.	IV.
SiO_2	67·84	61·95	49·82	76·67
Al_2O_3 ..	20·42	22·02	14·46	13·29
Fe_2O_3	0·01	0·82	4·78	0·42
FeO	0·32	0·51	6·75	0·56
MgO	0·14	3·98	5·42	0·01
CaO	0·67	3·02	9·86	0·17
Na_2O	9·54	6·13	4·98	4·34
K_2O	0·51	0·45	0·44	3·27
H_2O + ..	0·07	0·80	0·81	0·26
H_2O − ..	0·06	0·09	0·05	0·09
TiO_2	0·18	0·51	2·33	1·16
P_2O_5	tr.	n.d.	1·02	tr.
MnO	tr.	0·01	0·14	0·01
	99·76	100·29	100·86	99·95
Sp. Gr. ..	2·595	2·649	2·995	2·639

I. Albitite, 2 miles north-east of old May Downs homestead. Anal. G. A. Joplin.

II. Hybridized albitite, $5\frac{1}{2}$ miles east of old May Downs homestead. Anal. G. A. Joplin.

III. Albitized basic rock from the same locality as II. Anal. B. E. Williams.

IV. Albitite, contaminated by quartzite from the same locality as II. Anal. J. K. Burnett.

(*b*) The Granites.

i. The Coarse Porphyritic Granite.

This type occurs over a very extensive area and its most westerly outcrop has been termed the Templeton Granite. In this region it forms an almost continuous outcrop for at least 110 miles, and extends from about 22 miles north-west of Mount Isa to south of Rufus Creek. Another mass covers a wide area in the region of the East and West Leichhardt Rivers, but here the batholith is only partly unroofed and the outcrops are small and discontinuous. Another large mass occurs on the Dugald River, 15 miles west of Quamby, and extends north of Dobbyn.

The most westerly belt shows a marked foliation at its northern end, and farther south, near McKellars Bore, an augen structure is developed and felspar units measure up to 230 mm. in length. Still farther south, to the west of the Sulieman Bore, the granite is mainly massive and contains numerous de-orientated xenoliths. On the Leichhardt, the granite is mostly massive and in the Dugald area it is a true banded gneiss.

Although the porphyritic granites may be massive, gneissic or schistose in different places and are sometimes much hybridized, it is believed that they are all of the same age and that differences are due mainly to their tectonic environment; this is discussed later. In hand specimen the rock is coarse and porphyritic, with large pink phenocrysts of microcline from about 15 to 65 mm. in length.

Under the microscope the groundmass shows a range in grainsize from 0.5 to 3 mm., and consists of quartz, microcline, biotite and plagioclase, and it can be seen that accessory minerals are hornblende, iron ores, sphene, epidote and fluorite. The microcline may show slight albitization or alteration into myrmekite and scattered grains in the groundmass may show graphic intergrowth with quartz. The plagioclase ranges from oligoclase to andesine, and in the coarser grained rocks forms subidiomorphic laths or tabular crystals with turbid, partly saussuritized cores. The outer margin is clear but there appears to be no change in the composition of the felspar from core to margin, a feature noted by Nockolds (1931). In some rocks twin lamellae show slight bending, and other evidence of strain is shown by undulose extinction, banding and granulation in quartz and by the development of minute inclusions along curved lines which are possibly lines of conchoidal fracture in the quartz. Near McKellars Bore, epidote occurs along joint planes in the granite where slickensiding indicates post-consolidation movement.

Biotite may occur as large independent flakes up to 1.5 mm., in groups of large flakes or, more commonly, in clots of small criss-cross flakes associated with hornblende, sphene and iron ore. The latter occurrence suggests the presence of a xenolith that has reached a state of chemical equilibrium with the granite, but whose mechanical disintegration is not quite complete. The larger flakes may show bending and alteration to chlorite in the stressed granites, and strongly lineated types show a marked orientation of the biotites. Iron ores, sphene and apatite are common inclusions. Analyses of three of these rocks from widely spaced areas are shown in Table IV., where they are compared with two hybrids.

XENOLITHS AND HYBRIDS.

At the southern end of the most westerly belt near Sulieman Bore and in places on the Leichhardt River, numerous de-orientated xenoliths occur in the massive granite. These are mostly basic and consist of fine aggregates of biotite, hornblende and plagioclase. Some xenoliths are surrounded by one or more hybrid rings which show sharp contacts against the granite, against the xenolith and against one another. One interesting xenolith consists of a felted mass of slender carbonate needles and colourless amphibole, possibly representing an original fragment of dolomite. The quartz of the granite is idomorphic against the xenolith.

When the xenolith is of basic material, the hybrid immediately adjacent to it consists mainly of subidiomorphic tabular plagioclase, large grains of quartz and potash felspar in a fine base consisting of the minerals of the xenolith. In this base, biotite is more common than hornblende, and in some hybrids, myrmekite fringes potash felspar which is adjacent to plagioclase. Apatite and sphene are usually very abundant.

In the Duchess area a large mass of coarse, dark granite with phenocrysts of plagioclase invades a calc-silicate sequence in which basic igneous rocks are prominent. Although xenoliths are not common in this mass, on the analogy of the hybrids surrounding xenoliths elsewhere, it is assumed that the Duchess rock is a hybrid of the porphyritic granite. This is supported by a comparison of analyses (Table IV.). In many places along the Mount Isa-Duchess road, the granite has invaded basic schists, and its development seems to be a clear case of static granitization.

This rock is commonly foliated, and its composition and texture change slightly from place to place. In the main, it consists of highly saussuritized subidimorphic crystals of plagioclase, clots of chlorite, epidote and sphene, or of biotite, epidote and sphene, with interstitial quartz and microcline. In some types the potash felspar surrounds the plagioclase to give a monzonitic fabric. Plagioclase is saussuritized andesine which may contain large grains of epidote in the saussurite aggregate. Sphene and apatite are common accessories. These rocks contain more epidote than the hybrid rims around xenoliths in the western granites, and perhaps this may be accounted for by the higher lime content of the calc-silicate rocks which they invade. In the Dugald area, gneisses also are contaminated by calcareous material and their higher CaO content is expressed in a larger quantity of the normative anorthite (fig. 13).

Cataclastic structures are common and are particularly well shown in a rock which outcrops on a small hill west of Bushy Park.

TABLE IV.

——	I.	II.	III.	IV.	V.
SiO_2	72·68	71·26	70·77	70·29	68·63
Al_2O_3	12·83	13·95	14·97	12·59	15·18
Fe_2O_3	0·97	1·08	0·36	0·69	0·78
FeO	2·25	2·58	2·78	2·49	4·04
MgO	0·04	0·10	0·18	0·96	0·07
CaO	1·55	1·84	1·86	2·31	2·71
Na_2O	3·50	2·74	3·23	3·72	2·16
K_2O	5·03	5·65	5·04	4·72	3·71
H_2O + ...	0·50	0·37	0·39	0·64	0·87
H_2O −	0·02	0·07	0·12	0·08	0·04
TiO_2	0·43	0·26	0·68	0·78	1·35
P_2O_5	0·03	0·41	n.d.	0·38	abs.
MnO	tr.	tr.	tr.	0·02	abs.
CO_2	..	..	..	..	0·13
	99·83	100·20	100·38	99·57	99·67
Sp. Gr.	2·615	2·653	2·702	2·686	2·772

I. Porphyritic Granite. 5½ miles north-west of McKellar's Bore. Anal. G. A. Joplin.

II. Porphyritic Granite. Near head of Mica Creek. Anal. G. A. Joplin.

III. Porphyritic Granite (gneissic). Mountain Paddock, Dugald River, 15½ miles west-south-west of Quamby. Anal. G. A. Joplin.

IV. Porphyritic Granite Hybrid. 5½ miles west of Wills Creek on Duchess-Dajarra road. Anal. B. E. Williams.

V. Contaminated Porphyritic Granite (gneissic). Dugald River, 14½ miles south-west of Quamby. Anal. J. K. Burnett.

ii. The Microgranites.

These rocks form a narrow discontinuous outcrop on the eastern side of the porphyritic granite, west and south-west of Mount Isa, where they appear to occur as sheets and dykes. They also invade the porphyritic granite on the Leichhardt and its most easterly outcrop west of Quamby (Fig. 11). East of Quamby a belt of microgranite extends from south of Cloncurry to the north beyond Dobbyn, and so far as is known, this even finer-grained types is the predominating granite. Apparently related, but slightly more acid types occur in the Soldiers Cap area.

In hand specimen the rocks appear even-grained though different masses may differ in grain size. Under the microscope, however, a slight heterogeneity of grainsize is apparent and certain specimens show a range from 3 mm. to 0.2 mm. The constituent minerals are quartz, microcline, plagioclase and biotite, with apatite and iron ores as accessories. Muscovite, fluorite, sphene and chlorite are also present, and incipient alteration of potash felspar to myrmekite is common. Micrographic intergrowth of quartz and orthoclase is present in some specimens.

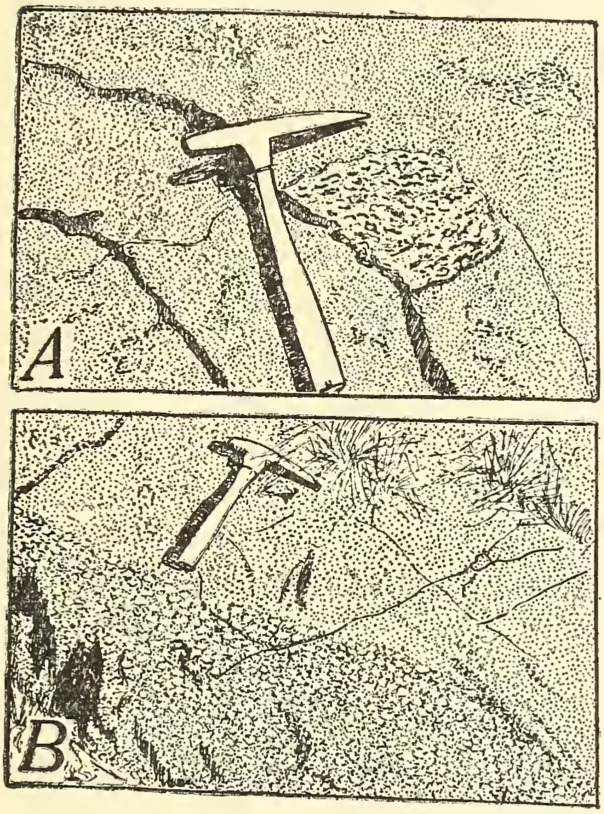


Fig. 11.

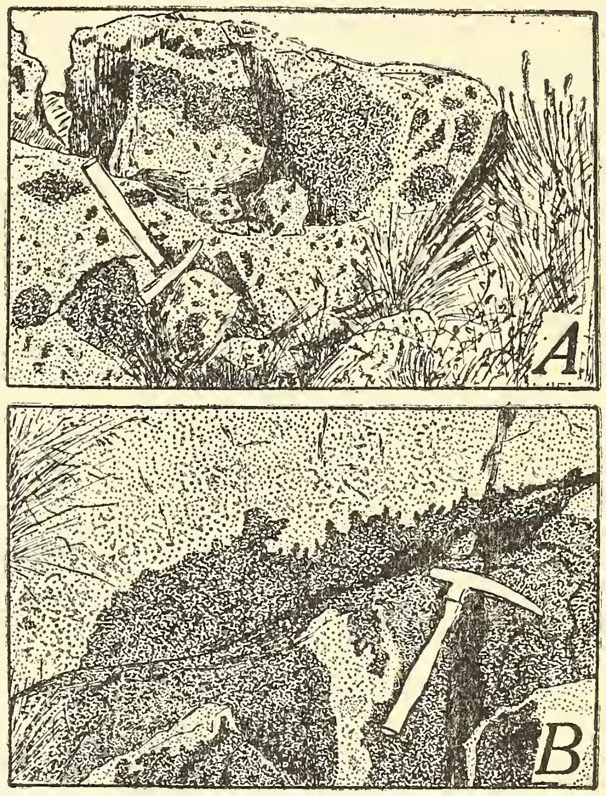


Fig. 12.

Text-fig. 11.

A. Microgranite with inclusion of porphyritic granite.

B. Microgranite showing transgressive relation to porphyritic granite.

Text-fig. 12.

A. Basalt xenoliths in microgranite. East of old May Downs homestead.

B. Basic xenolith with crenellated border and vein of intrusive granite.

The plagioclase ranges from oligoclase to andesine and forms subidiomorphic tabular crystals with turbid cores. The alteration is chiefly to sericite, but saussurite may occur. The turbid cores are commonly rounded and surrounded by a clear rim which shows interlocking with the other minerals forming the granular base. Although the plagioclase crystals are larger than those of the granular mosaic, they can scarcely be classified as phenocrysts.

Quartz occurs as irregular grains in the mosaic, or as interstitial patches between crystals of plagioclase, and in some rocks it forms larger grains resembling small phenocrysts. Undulose extinction is common.

Microcline is abundant and may form large, irregular grains, though normally their size is comparable to others in the mosaic. Myrmekite fringes or replaces microcline when it is adjacent to plagioclase and micrographic intergrowths with quartz have been noted.

Biotite is not abundant and commonly occurs in small equally distributed flakes; in some rocks it is absent. Alteration to chlorite is frequent and sphene is associated. Near the Dugald Fault, on the Cloncurry Road, slight hybridization is evidenced by the presence of clots of chlorite or of biotite and muscovite with associated granular epidote, sphene and iron ores. On the Kajabbi Track, about 7 miles north of Quamby, slight basification is indicated by the presence of a little hornblende.

Sphene may be relatively abundant, and while it commonly occurs in granular masses surrounding iron ore or in aggregates associated with biotite, it may form independent wedge-shaped crystals up to 0.7 mm. which have crystallized late and wrap grains of quartz and felspar.

These granites have been subjected to post-consolidation stresses and a marked lineation is apparent in the field. This is especially noticeable on Mica Creek and near Cloncurry. Under the microscope quartz shows undulose extinction, granulation and banding, plagioclase may show bending of the lamellae, biotite may be bent and chloritized and epidote may occur in small lenses. In extreme cases, possibly near a fault zone, a mortar structure is developed and clear grains of quartz and microcline and turbid grains of plagioclase are set in a mylonite-like matrix of chlorite and quartz.

Near Cloncurry, at the turnoff between the Mount Isa and Quamby Roads, granites of three different textures are developed; one shows chilled margins against the other, and biotite is developed at the contact.

Xenoliths and Hybrids.

East of the old May Downs homestead the fine pink granite invades a sequence of basalts with interbedded quartzites, and as this intrusion is only partly unroofed, xenoliths are very numerous (Fig. 12). The majority of the xenoliths are basic and the granite in their vicinity is basified, but some sedimentary fragments occur and the granite has been slightly acidified by their assimilation. About a mile south of Carters Bore the fine granite is also crowded with xenoliths, and these are mostly of sedimentary origin. Near the head of Mica Creek the granite also contains numerous xenoliths in every stage of disintegration. These measure from about 20 to over 300 mm. in diameter. The granite shows a slight directional structure, but as some of the xenoliths show sedimentary bedding and are de-orientated, the parallel structures in the granite cannot be interpreted as relict bedding. Xenoliths also occur in the fine grained granite of the Cloncurry-Kajabbi mass, but no systematic collecting has been done in this area.

East of May Downs homestead, the xenoliths range in size from a few to many hundreds of millimetres, and they are usually angular. In one place the granite has invaded a schistose basic rock, possibly in a fault zone, and the magma has encroached along the planes of schistosity, with occasional transgressions, and the detached xenoliths have a peculiar crenellated border (Fig. 12B). The junction of the xenolith with the hybrid is commonly quite sharp, and there may be several rings of hybrid material surrounding each xenolith. One such xenolith and inner ring have been analysed and the results are shown in Tables II. and V. This xenolith consists of a fine (0.2 mm.) aggregate of green biotite, epidote, plagioclase, hornblende, sphene and a little quartz. The felspar tends to a lath-shape and the other minerals occur as irregular grains. The plagioclase is very turbid and biotite surrounds granular sphene. The xenolith is surrounded by a clear rim varying in width from 1 to 1.5 mm. consisting of quartz and myrmekite. This is surrounded by an acidified basic rock consisting of large (3 mm.) interlocking grains of quartz, subidiomorphic microcline and plagioclase in a finer base of the same minerals together with much greenish-brown biotite. Further away from the xenolith, a more normal granitic texture is developed and biotite forms large flakes up to 1 mm. across. In this type, plagioclase forms tabular crystals of about 1 mm., and these are surrounded by a mosaic of quartz, plagioclase, biotite and hornblende. Sphene and iron ores are accessory. Some of the plagioclase grains in the groundmass have a sieve-structure, suggesting recrystallization, and it is likely that they have been mechanically incorporated.

TABLE V.

—	I.	II.	III.
SiO_2	73·49	74·76	63·98
Al_2O_3	14·06	14·01	16·75
Fe_2O_3	0·37	0·83	1·95
FeO	1·74	0·71	3·84
MgO	0·01	0·32	1·59
CaO	0·96	0·63	5·10
Na_2O	2·68	2·07	4·05
K_2O	5·63	6·04	1·67
H_2O +	0·33	0·35	0·30
H_2O −	0·03	0·01	0·06
TiO_2	0·78	0·37	1·09
P_2O_5	tr.	0·11	0·34
MnO	tr.	tr.	0·11
CO_2	abs.	abs.	0·69
	100·08	100·21	100·52
Sp. Gr.	2·623	2·594	2·763

I. Microgranite. Junction of Mount Isa and Quamby roads, Cloncurry. Anal. J. K. Burnett.

II. Microgranite. East of old homestead, May Downs. Anal. J. K. Burnett and B. E. Williams.

III. Highly basified microgranite from ring around xenolith. (Anal. II., Table III.). Same locality as II. Anal. G. A. Joplin.

Other xenoliths show slight variation of these features, but are essentially similar. One, from the same locality, is a little richer in magnesia, and hornblende predominates, occurring in a fine (less 0.1 mm.) granular assemblage with plagioclase, epidote and biotite. The mica may form poikiloblasts enveloping the other minerals (fig. 10B.). One hybrid from this locality contains an abundance of scapolite. Most of it is fresh, but one or two grains are altered and fibrous and may be remnants from an earlier scapolitized basic rock. A little fluorite is also present. The least basified hybrids contain large (3 mm.) irregular grains of microcline and turbid plagioclase in a granular base of quartz, biotite, felspar and myrmekite.

Sedimentary xenoliths are mainly psammites and psammopelites. Near Carters Bore, a fine grained sedimentary xenolith shows porphyroblasts of turbid plagioclase surrounded by an extremely fine granoblastic mass of quartz, biotite and felspar (fig. 10C.). The marginal granite also contains turbid felspar, quartz, microcline and biotite, and the additional quartz in these rocks indicates acidification by the sediment.

Very similar types occur on May Downs where the granite has assimilated quartzites interbedded with basalts. As noted above, the granites have been basified at this locality, but many xenoliths are studded with rounded and highly sutured grains (about 0.4 mm.) of quartz, suggesting the mechanical disruption of the sediment by a basified magma. In some types, the iron ore occurs in small rods which may show a rough parallelism indicative of a relict bedding.

iii. The Pegmatites.

Large dykes of coarse pegmatite occur sporadically on the eastern margin of the western batholith and consist mainly of quartz, microcline and white mica. The mica has been mined on Mica Creek, and monazite also is recorded from this locality. About 6 miles west-south-west of Mount Isa a pegmatite contains beryl and red garnet. Graphic structures are common.

The pegmatite dykes invade both porphyritic granite and microgranite and some of them show evidence of post-consolidation stress. As these rocks will be the subject of a more detailed study by a member of the staff of Mount Isa Mines Ltd., it is not proposed to treat them in any detail here.

VII. TYPES OF BATHOLITH.

It has long been recognized that large plutonic masses, predominantly of granitic and granodioritic composition, invade the geosynclines at, or shortly after, their compression. Blackwelder and Baddley (1925) studied the relation of batholiths to the schistosity of the country rocks, and their statistical summary indicates that 67% show transgressive relations with the former schistosity entirely obliterated by thermal metamorphism; 10% show schistosity parallel to the periphery of the batholith, indicating recrystallization under compression; and 22% were of lenticular form with all related structures parallel to the regional cleavage. They attribute these differences to different erosion levels.

Closely comparable observations were made by Per Geijer (1916) in Central Sweden where he noted a younger group of Archaean granites, with transgressive relations, associated with folding and faulting; whilst older granites invade the anticlines in closely folded areas and show concordant relations. These he called anticlinal batholiths.

Billings (1928) recognized two types of batholith in the Conway Quadrangle of New Hampshire. The concordant, he believed, were associated with the folding movement and he termed them synchronous batholiths; the transgressive, he considered, were injected after folding, and he termed them subsequent. Following the terminology of Billings, Brown (1931) drew up lists of the characteristics of each type and illustrated them by reference to New South Wales examples. Like Billings, he considered that the differences are due to their relation to the main compressional force, but he pointed out also that in part it may be a function of depth.

Cloos and Chudoba (1931) figured a section of a hypothetical intrusion which showed concordant and transgressive relations related to depth. Goldschmidt (1911, 1920) recognized two types of metamorphism associated with batholiths; thermal metamorphism (Kristiania Type), and injection metamorphism (Stavanger Type). Moreover, these two types of metamorphism are apparent in the Younger and Older Granites of the British Isles.

Hence it is evident that at least two types of batholiths exist, and that the differences have been variously attributed to age, to depth and to their relation to the compression. The present writer believes that there is a third type of batholith which shows some characters intermediate between the other two. Cloos and Chudoba (1931) and Blackwelder and Baddley (1925) have also recognised an intermediate type, the former authors showing them at an intermediate depth. Brown (1931), in discussing examples of the synchronous batholith, has remarked that the Murrumbidgee Batholith is "an intrusion which is of synchronous type, but which lacks some of the characters listed." These intermediate batholiths are concordant, and the plutonic rock commonly shows directional structures parallel to the schistosity of the country rock, but unlike the typical synchronous batholith, they are not associated with high grade regional metamorphism nor with regional granitization. Nevertheless, they are not transgressive nor are they associated with thermal metamorphism. They are associated with low-grade schists upon which has been superimposed a hydrothermal or pneumatolytic alteration. The batholith west of Mount Isa is of this type and it is proposed to call it a quasi-synchronous batholith, because of its close affinity to the synchronous type.

Because the same type of granite is so widespread in the Mount Isa-Cloncurry area, it affords a unique opportunity for the study of batholiths. The porphyritic granite in the Dugald River area is concordant and strongly gneissic, and the country rocks are in the sillimanite-zone. There is only very slight evidence of granitization, but this may be inhibited by the composition of the country rocks, which are mainly calcsilicates. This batholith therefore may be regarded as a synchronous example.

On the Leichhardt River and at Duchess, the porphyritic granite is slightly transgressive, it is associated with thermal metamorphism and static granitization, and at Duchess it is markedly hybridized. Thus it would seem that these masses are of the subsequent type.

All consist of the porphyritic granite, and reference to Table V. will show that their composition is fairly uniform and there is nothing to suggest any difference in their age.

The synchronous batholith of the Dugald River invades calcsilicates which are believed to be on the same horizon as the calcsilicate hornfelses of the Duchess Area, and possibly these may be correlated with the Mount Isa Shale which is invaded by the quasi-synchronous batholith. When the Bureau Bulletin is published it will be shown that the acid lavas, invaded by the subsequent batholith on the Leichhardt, underlie the calcsilicates. Therefore, it would seem that depth of burial is not responsible for the differences between these batholiths, and their relation to compression will now be considered.

It is noteworthy that the strongly compressed synchronous batholith of the Dugald River area is near the centre of this Proterozoic geosyncline, and not only was it subjected to lateral pressure, but no doubt it was under a heavy load. The Leichhardt mass also is near the centre of the mobile belt, and conditions might be expected to be the same, yet it is of the subsequent type. The Dugald Batholith invades incompetent and highly folded calcareous rocks, whilst the Leichhardt mass invades resistant acid lava. Thus it would seem that the physical properties of the country rocks were the controlling factors. In this event, the terms synchronous and subsequent do not apply.

The origin of the so-called quasi-synchronous batholiths needs further investigation. There is a suggestion that they have been subjected to an intermittent compression, and this might be possible on the edge of the geosyncline near a zone of thrusting. The batholith west of Mount Isa occurs in such a position where the load would be less than that of the centre and where some protection would be afforded by the borderland of older rocks. In this case therefore the position of the batholith within the geosyncline may be significant. There is no field evidence of thrusting in the immediate vicinity of the granite in the Mount Isa region, but there is reason to believe that the intrusion was emplaced in the old basement rocks under a comparatively shallow cover of the Lower Proterozoic strata.

It is therefore concluded that the different types of batholiths are related to their position within the geosyncline at the time of injection, and that the degree of competence of the country rock plays an important role.

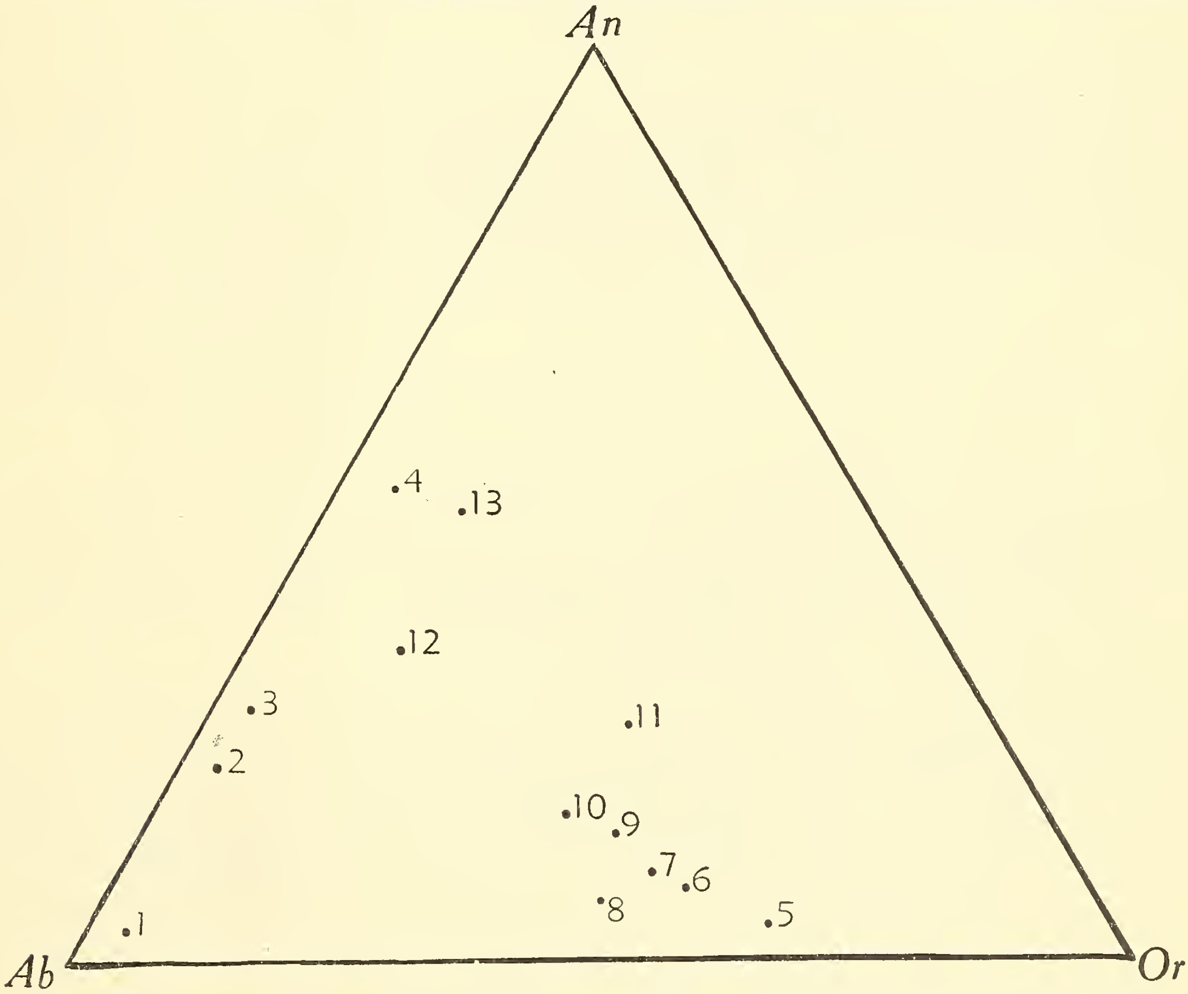
VIII. ORIGIN OF THE GRANITES.

It has been held by many that the granites of the Mount Isa-Cloncurry area have been formed as the result of granitization, but with this view the present writer does not concur. It is true that an examination of the aerial photographs reveals trend lines in the granite which appear to be continuous with the surrounding sedimentary structures; that many of the granite masses are concordant; that many of the granites are porphyritic; and that the contacts are indistinct in many places. These facts, however, do not prove granitization, though they are worthy of careful field and laboratory examination.

In the company of Mr. E. K. Carter, a trip was made into the rough granite country on the May Downs property north-west of Mount Isa, where strong structural lines showed on the aerial photographs. These proved to be remnants of arkose, highly contact altered and partly granitized. In most places the contact with the granite was sharp and the masses appear to be either roof-pendants or screens. Detailed mapping has been impossible, but it seems likely that the western batholith was emplaced by a number of concordant injections, possibly separated by screens of the country rock, or of earlier phases of the igneous rock. Undoubtedly some static granitization has taken place, particularly in such susceptible rocks as arkose or dacite, but these form a very small part of the sequence invaded by the western batholith. Actually the country rocks in this part of the area are mainly basalts and quartzites, and it is difficult to assume that such rocks could be granitized to form granites with the composition shown in Table IV. Undoubtedly some of the granites have been strongly basified and more analyses would probably show a wider range of composition, but the three analysed rocks were chosen from amongst the least basified types, and as they are many miles apart, there seems some justification for assuming that they represent one magma. They preserve marked uniformity, even though the country rocks on the Dugald River are mainly calcsilicates.

Where it can be shown that reaction has taken place between basalts and granite magma, it is significant that intermediate hybrids are developed. In fig. 13, an attempt is made to show the relationship of these granites and hybrids to one of the basalts. Obviously none of these types can be represented by a single point, and when more analyses are available, it is likely that the basalts, granites and their hybrids will occupy overlapping fields. At point 11, although the Ab :Or is comparable to the other granites, it is displaced towards An indicating assimilation of calcerous material. In the absence of further chemical work this diagram is included as a possible pointer towards the origin of the porphyritic granites and their hybrids. Furthermore, the diagram clearly indicates that the albitite is the parent of some of the hybrids.

Near Duchess there is much evidence to show that the granite has been hybridized by the basic country rock, and that xenoliths of the country rock have been acidified to give a complex series of hybrids. Some of these are undoubtedly the result of static granitization, where but little acid magma has been added to the solid basic rock. Other hybrids



Text-fig. 13.

Triangular diagram showing plots of granites, basalt and hybrids based on normative albite, orthoclase and anorthite. 1. Albitite; 2. Hybridized albitite; 3. Albitized basic rock; 4. Basalt; 5. Microgranite (May Downs); 6. Microgranite (Cloncurry); 7. Porphyritic granite (Mica Creek); 8. Porphyritic granite (near McKellar's Bore); 9. Porphyritic granite (Dugald River); 10. Hybridized porphyritic granite (Wills Creek); 11. Contaminated porphyritic granite (Dugald Area); 12. Hybridized granite surrounding basic xenolith; 13. Basic xenolith.

TABLE VI.

Tectonic.	Magmatic.	Metamorphic.
Sinking Trough	Outpouring of Acid Lavas	
Partial stabilization ..	Outpouring of basic lavas. Dykes and sills cutting acid lavas	..
Compression of varying intensity in different parts of geosyncline	..	Regional metamorphism. Chlorite and biotite zones on west. Staurolite and garnet schists locally near Soldiers Cap and west of Wee MacGregor Mine
Thrusting from east ..	..	Retrograde metamorphism superimposed on regional along shears
Relief of compression ..	Small bosses of gabbro injected in noses of folds and along faults	..
Renewed compression and yielding of incompetent rocks in centre of trough. Relief by thrusting on edge of trough	Uprising of magma to form porphyritic granite. Hybridization of magma under fairly static conditions on edge of trough	Contact metamorphism and static granitization of competent acid lavas; contact metamorphism of calcsilicates on edge of trough, and piezo-contact metamorphism and some synkinematic granitization of incompetent calcareous rocks in deeper part of trough
Strong local compression from west near Mount Isa	Squeezing out of partial magma on east. Alignment of minerals in crystal mush	Greisenization of low-grade regionally altered schists
Static period. Slight compression in places	Emplacement of fine even-grained granites (?) possibly emplacement of albitites	(?) Mineralization along fault zones, regional scapolitization, contact metamorphism and static granitization
Tension	Pegmatite dykes	Continued mineralization
Slight local compression ..	..	Directional structure in pegmatites and slight shearing of some even-grained granites

have formed as the result of crystallization of a basified magma. An examination of certain xenoliths indicates that static granitization has been brought about mainly by the mechanical forcing apart of the xenolith by porphyroblasts of microcline or plagioclase, and by the intergranular deposition of quartz and myrmekite.

Reference to fig. 13 shows that all the analysed porphyritic granites indicate some slight hybridization, but their uniformity suggests that this may have taken place at greater depth, where in fact the magma may have arisen as a result of granitization of pelitic sediments (Joplin, 1952). It seems certain, however, that the granite was injected as a magma at the present level of erosion in this region and this is further supported by the presence of de-orientated xenoliths on the southern end of the western batholith in the region of the Sulieman Bore. The fine pink granite injects the porphyritic as veins and sheets, and in many places it is crowded with de-orientated xenoliths; its magmatic origin, therefore, seems beyond question.

IX. TECTONIC, MAGMATIC AND METAMORPHIC HISTORY.

Although much detailed work needs to be done before these histories can be written, a bold attempt is made in Table VI. to correlate the sequence of magmatic and metamorphic events with the possible phases of the diastrophism. At present it is not possible to date either the scapolitization or the mineralization with any certainty, and the placing of all other events is only an interpretation of the data at present available. Nevertheless, such a Table serves a useful purpose in assembling the data and possibly suggesting future lines of investigation which may throw further light on dating these events.

X. SUMMARY AND CONCLUSIONS.

The paper contains brief descriptions of a group of ortho- and para-gneissis that are believed to be part of the basement upon which the Lower Proterozoic succession was deposited. Four chemically distinct types of country rock are described in the Lower Proterozoic, namely, aluminous and siliceous rocks, calcareous and calcsilicate rocks, a sequence of acid lavas and a sequence of basic lavas and intrusives. These are invaded by albitites, coarse porphyritic granite, microgranites and pegmatites. The types of batholith present in the areas are discussed and it is concluded that the differences between them are due partly to their position within the geosyncline and partly to the nature of the country rocks which they invade. The origin of the granites is briefly discussed and an attempt is made to relate the magmatic and metamorphic episodes to the tectonic history of the area.

In conclusion the writer would like to emphasize that this work is only a preliminary account, and that certain ideas may require modification or correction when more detailed studies are undertaken. It is hoped that detailed work on the tectonic history, on the older complex, on the albitites, on the basic rocks and on the pegmatites may be carried out in the near future.

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Vol. LXVI., No. 5.

URANIUM MINERALIZATION IN THE CLONCURRY-MT. ISA AREA.

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Communicated by Professor W. H. Bryan.

(With two Plates and two Text-figures.)

(*Received* 10*th November*, 1954; *issued separately*, 19*th September*, 1955.)

INTRODUCTION.

The discovery of metatorbernite from Mt.Cobalt early in 1954 by the author and by geologists from Mt.Isa Mines Ltd. has been followed by the discovery of other uranium occurrences over a wide area in the Cloncurry-Mt.Isa area. Radio-active material has been found sporadically from west and north-west of Mt.Isa to a point twelve miles east of Cloncurry, and from Mt.Cobalt in the south to near Kajabbi in the north.

The impressions formed by the author as to the nature and origin of the various occurrences are based upon a brief field survey of a number of mine leases. Some of the views expressed are somewhat tentative, but are not lacking in field and laboratory evidence.

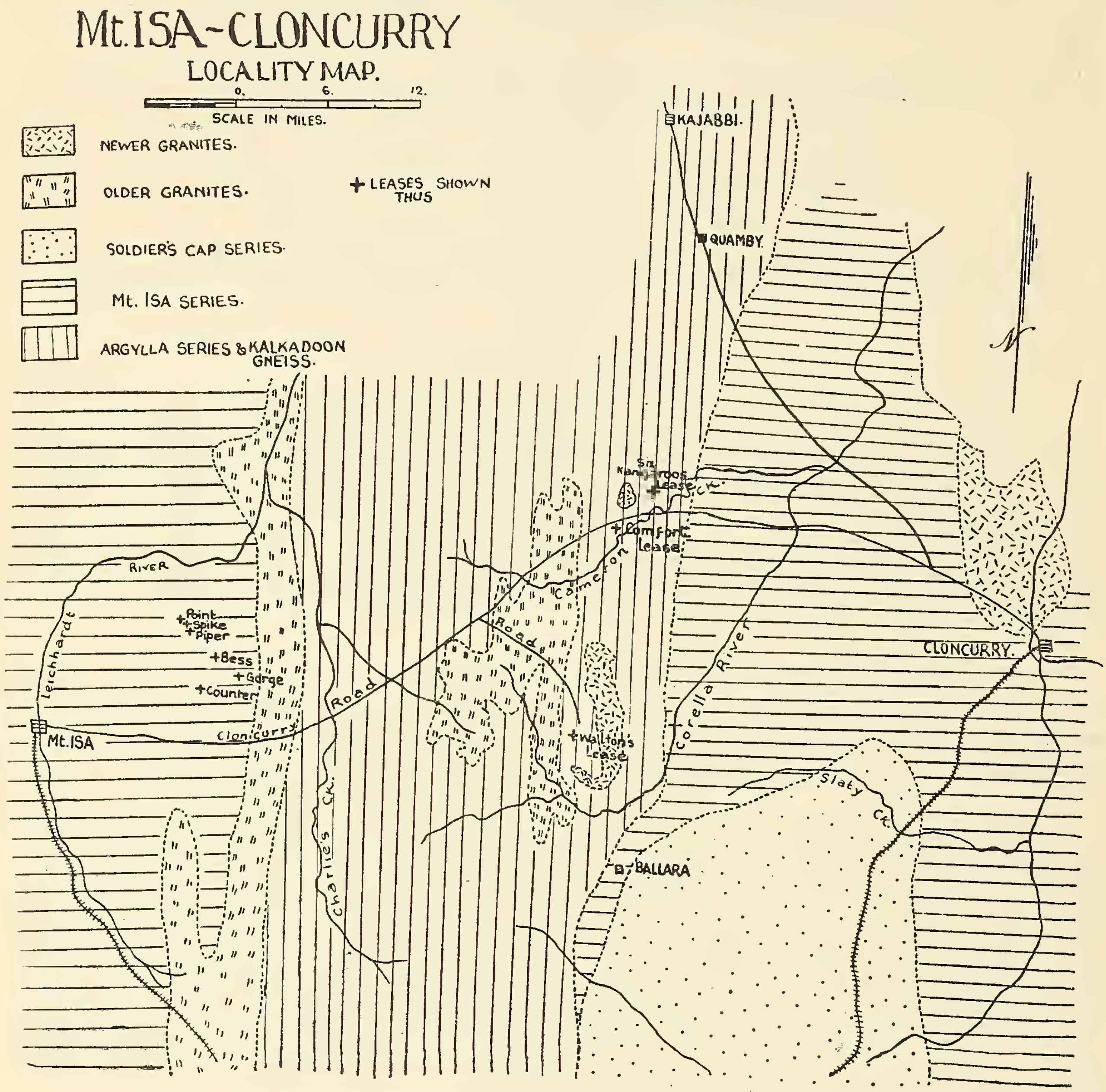
The stratigraphy and structure of the area have been interpreted differently by different workers. Recently doubt has been expressed as to whether or not a tectonic break exists between series conventionally regarded as Lower Pre-Cambrian and those regarded as Middle Pre-Cambrian. The country to the west (Mt.Isa and environs) has been delineated in some detail by Carter (1953) and Knight (1953). The country to the east and north has not been studied in such detail, though an excellent working basis has been provided by Honman (1935-36), Sheppard (1946) and Jones (1953).

For the purposes of identifying the stratigraphic position of the various occurrences, the author has used the stratigraphic terminology proposed by Browne (in David 1950). Reference is made herein to the Argylla Series and the Kalkadoon Gneisses (Lower Pre-Cambrian), the Mt.Isa Series (Middle Pre-Cambrian) and to the Templeton intrusives of late Middle Pre-Cambrian age.

NATURE AND ORIGIN OF MINERALIZATION.

Specific occurrences are referred to according to lease names, the positions of which are indicated on the accompanying locality map.

There is evidence of trace mineralization within small lenses of sodic migmatite as replacement of felspar by small grains of an unidentified radio-active mineral. These migmatites occur as concordant veinlets and lenses, up to six inches in length, in Argylla schists in a creek bed near the main road ten miles east of Mt.Isa. This occurrence, of mineralogical interest only, seems to bear no relation to an adjacent intrusive mass of gneissic granite. The occurrence is similar to the mineralized migmatites of the Archaean of South Australia and the Northern Territory. No doubt other such mineralized migmatites occur elsewhere in the Mt.Isa-Cloncurry area.

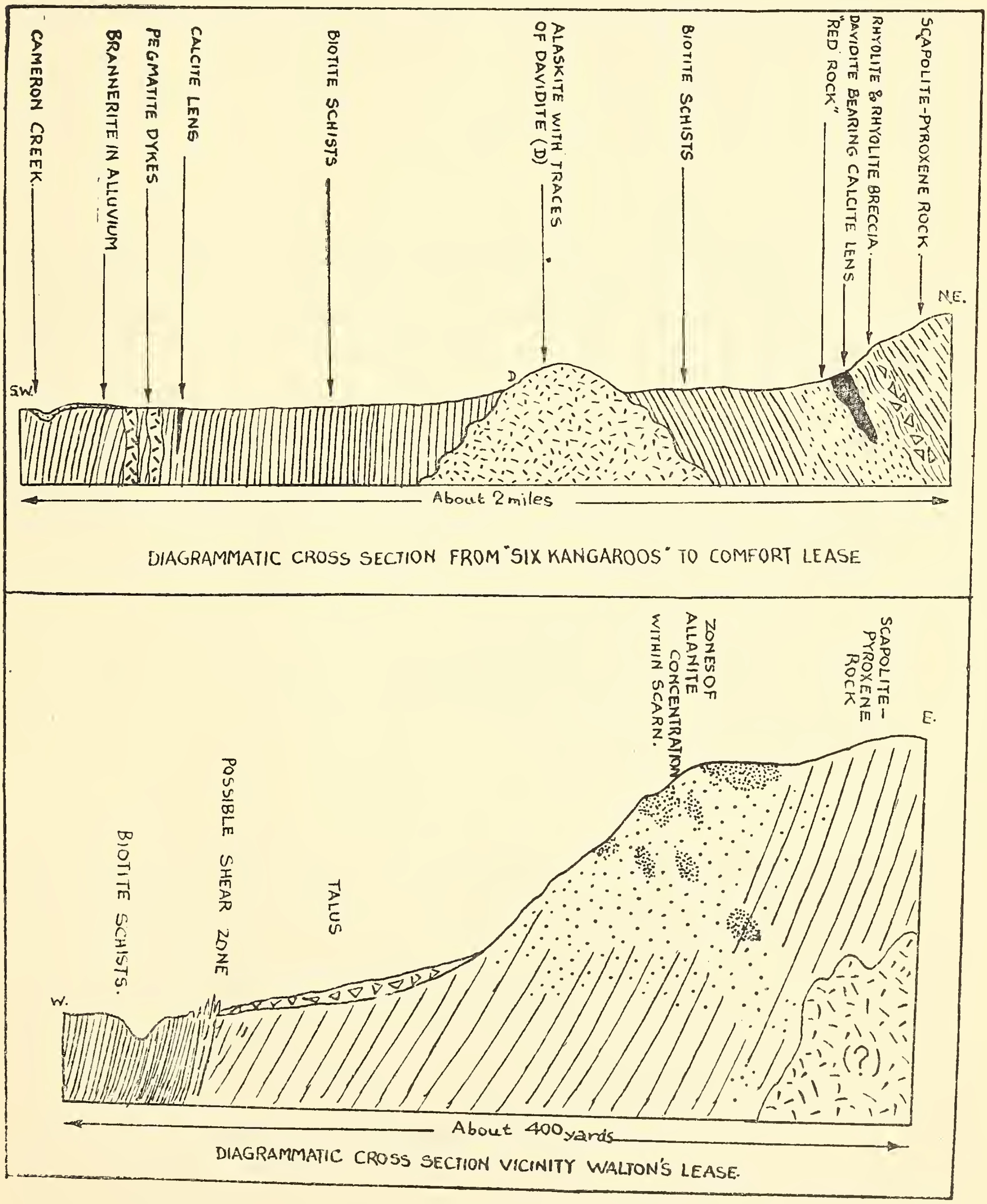


Text-fig. 1.

At the Comfort lease adjacent to the main road, midway between Mt.Isa and Cloncurry, similar biotite schists occur trending north-south. Outcrops are poor, the greater part of the lease being covered by detritus. An extremely radio-active mineral occurs here as eluvial pieces up to two inches in diameter. Chemical tests show the mineral to contain calcium, iron, titanium, thorium and uranium; the uranium content being 31·2% U_3O_8. The mineral is black and vitreous on a fresh face, but is resin-coloured toward the exterior. It weathers to a cream-coloured ochre containing much titania. The fracture is conchoidal and the streak brownish-green. The hardness of the mineral is a little over 4, and the specific gravity 4·8. This mineral is almost certainly brannerite, an uranium, calcium, iron, rare earth titanate originally recorded from Kelly Gulch, Idaho, where it occurs as detrital grains in a gold placer (Palache *et. al.*, 1944), and more recently from Ontario, Canada (Nuffield, 1954).

The brannerite is not seen *in situ,* and it was not found during a systematic search in a dyke of unstressed granite pegmatite of Templeton age concordantly intrusive into the schists. It is believed that this uranium mineral occurs in lenses of migmatite within the schists, now covered by detritus. The occurrence does not appear to be extensive.

An interesting feature of the geology of this lease is the presence of a discontinuous bed of coarse calcite in the biotite schists. The origin of the bed is obscure. It shows no evidence of shearing, even though perfectly conformable with the direction of schistosity of the enclosing biotite schists. By comparison with other occurrences on the



Text-fig. 2.

Spike lease and Six Kangaroos lease (*q.v.*), it would appear that the calcite lenses represent surplus lime which has migrated from the metamorphosed country rock to zones of tension possibly during intrusions by Templeton granite and pegmatite.

One and a half miles north from the Comfort lease are a number Spike lease and Six Kangaroos lease (*q.v.*), it would appear that the leases is a zone of pyroxene-scapolite granulite of the type recently described by Edwards and Baker (1953). These form sharp ridges one hundred feet above the otherwise flat surface. The granulites are in contact with felsitic rhyolite and agglomerates. The volcanics give way to a fine-grained haematite rich rock which may be similar to the ''red rock'' described by Edwards and Baker (*op. cit.*). The zone of ''red rock'' is followed by biotite schists which, by hydrothermal alteration, may have given rise to the former.

The interesting feature of this locality is the presence, within the ''red rock'', of an irregular mass of coarse calcite which has a pseudo-intrusive relationship to the country rock. The calcite has suffered thermal metamorphism at certain points with the production of bright green actinolite.

These metamorphic patches are sporadic in occurrence within the calcite mass. Also sporadic are pieces of davidite up to one pound weight, but generally smaller. The calcite, however, does not appear to be richly endowed with this mineral. The origin of this calcite mass is likewise obscure, but the author finds it difficult to postulate an origin not related, in some way, to the migration of lime and titania from the adjacent metasediments. Edwards and Baker have noted the presence of ilmenite in the metamorphosed sediments of other parts of the Mt.Isa-Cloncurry area.

On the western border of the leases the strata are intruded by a circular boss of alaskite from which issue graphic pegmatites. Both are of a non-stressed character. At one place on the western fringe of the granite, a small quantity of davidite occurs replacing felspar (plate IV., fig. 1), but here again, the quantity seems to be limited. The enclosing granite is stained by small patches of pale blue and bright yellow uranium oxidized products. There is no doubt that this alaskite granite and its pegmatites belong to the period of ''newer granites'' and that the occurrence at Six Kangaroos represents a second generation of this rare mineral in the Mt.Isa-Cloncurry region. However, the possibility that the davidite may have been derived from the metasediments during intrusion should not be overlooked.

The occurrence of uraniferous material at the Mary Kathleen (Walton's) lease offers a fascinating study as regards paragenesis and origin. This lease is located forty miles east of Mt. Isa. Paragneisses and mica schists occur along the western border of the lease and may be well observed in a creek on the fringe. These rocks are in close juxtaposition with heavily sheared pyroxene granulites which, in a less sheared condition, also outcrop as high ridges on the eastern border. The strike of the metasediments is due north-south. The heavy shearing of the granulites on the west is due to faulting along the strike.

The central portion of the lease, between the two belts of pyroxene granulite, is occupied by an area of thermally metamorphosed calcareous rock. Macroscopically, the rock is a uniform brown colour, aphanitic in texture, and possesses a greasy lustre. Under the microscope it is seen to consist of large patches of brown colour-zoned grossularite and green hedenbergite. The rock is a typical scarn. The scarn grades into another rock type of a brownish-black colour and minutely crystalline texture. Microscopically (plate IV., fig. 2) this rock consists of allanite in subhedral to anhedral grains up to 2 mm. in length, but generally smaller. The mineral is pleochroic from light brown to dark brown and is sometimes twinned. Some grains are very dark in colour, nearly opaque, and represent the same mineral in a quasi-metamict state. The allanite accounts for some 80 to 90 per cent. of the rock. The remainder consists of metamorphic apatite, epidote and a mineral believed to be lawsonite. The texture of the rock is granoblastic with the merest suggestion of lineation. Pending further investigation this material has been termed uraniferous allanite (see table of uranium content). Uranium oxidized products occur sparingly along joints in the allanite rock. Among these is autunite which exhibits its characteristic fluorescence under ultra-violet radiation.

Edwards and Baker have indicated the presence of orthite (allanite) as cores surrounded by epidote in the scapolite marble at Duchess and elsewhere in the Mt.Isa-Cloncurry area. The origin of the scapolite rocks has been described by these workers as due to ''regional pneumatolytic metasomatism''. There is no doubt that the development of the allanite rock was simultaneous with the regional scapolitization of the calcareous sediments of this locality, and derives from a local concentration of rare earth volatiles with some supervening contact metamorphism. Templeton granite outcrops within half a mile of the lease, and though unstressed, is elongated north-south, parallel to the strike of the sediments in this locality.

North-west of Cloncurry, between Quamby and Kajabbi, in monotonously flat terrain, schists and scapolite granulites are concealed over considerable areas by thin coverings of desert outwash silts. Granites and tourmaline pegmatites of Templeton age occur in places. At a number of localities in this district, irregular fragments and loose crystals of iron ore occur and are mostly coated with desert varnish.

A random collection of these pebbles varied as follows:—(i.) High radio-activity and very strong magnetic susceptibility. (ii.) High radio-activity and weak magnetism. (iii.) No radio-activity and strong magnetic properties. (iv.) Neither radio-activity nor magnetism. Tentatively these pebbles are regarded as uraniferous ilmenite-magnetite intergrowths with varying uranium content and showing various stages of oxidation to haematite.

Twelve miles east of Mt.Isa in country dominated by high ridges of white quartzite of the Mt.Isa Series are a number of leases known respectively as Counter, Bess, Spike, Point and Piper. The leases are located in gently undulating terrain in an open valley bordered by the quartzites.

The country rocks consist of dark grey coloured chloritic quartzites, reddish to purplish grey coloured shales and hornfels, calcareous shales and some epidotized basic lavas. The latter appear to be the basal beds, but are not continuous in outcrop. Some sheared conglomerate occurs within the series. The sediments are broadly folded with dips of about 45°. Except where strong shear zones occur, none shows any sign of advanced metamorphism.

Each of these leases contains small areas of high radio-activity, and uranium oxidized products have been noted.

At the Counter Lease, uranium has been found in the chloritic quartzites. In each of the other leases mentioned, uranium occurs in small quantities only in the purplish-grey hornfels member. Thin section studies show the hornfels to contain flakes of biotite, nests of plagioclase, calcite and some quartz. None of these minerals could carry the uranium proven by chemical analysis. This element must, therefore, occur in the host of minute metallic grains observed only in thin section (plate V., figs. 1, 2). These grains are readily extracted from the crushed rock by means of a small magnet. The chloritic quartzite from Counter Lease contains a substantial quantity of magnetite crystals (plate V., fig. 2) and possibly some ilmenite.

Uranium search, up to the present, would indicate that the other members of the Mt. Isa Series do not contain uranium. This proposition, however, should be treated with some reserve at this stage of exploration. Thin section study, together with the fact that the uranium bearing grains are confined to one or two sedimentary units, suggests a geosynclinal origin. Lack of severe tectonism has allowed the grains to remain much in the same state as they were deposited.

At the Bess Lease, there is evidence of small scale copper mineralization. A small lens of chalcopyrite six inches in length occupies a tensional gash in the hornfels. Minute particles of the same mineral are seen to diminish in concentration away from the chalcopyrite filled opening. There is no evidence of vein quartz or other gangue materials. This isolated occurrence may also represent geosynclinal mineralization with a degree of ionic migration toward a zone of pressure relief.

SUMMARY AND CONCLUSIONS.

Low grade uranium mineralization occurs in the Cloncurry-Mt.Isa area as follows:—

1. As a constituent of ilmenite-magnetite in schists of the Argylla Series; also as brannerite in sodic migmatites in the schists. The uraniferous iron ores are a product of regional metamorphism, and there may be a correlation with the magnetite bearing chlorite schists of the Broken Hill District.

2. As a "pneumatolytic" constituent of alaskite granite of Templeton age.

3. As a constituent of allanite rock of pyrometasomatic origin.

4. As a heavy mineral concentrate in certain unstressed sediments of the Mt.Isa Series, derived from erosion of the uranium bearing Lower Pre-Cambrian metasediments.

The author is of the opinion that the best chances of economic production lie with the Mt.Isa sediments. A considerable amount of very detailed stratigraphic study and mapping will be necessary in order to establish the structure and sub-surface distribution of these beds. Local tectonic disruption, folding and the natural streaky character of heavy mineral concentrates in sediments may prove hazardous. The possibility that these uraniferous concentrations are too few in number and their overall tenor too low for substantial production, must also be considered. Walton's should be a significant producer.

Results of chemical assays of samples from the various occurrences referred to are contained in the accompanying table.

TABLE OF URANIUM CONTENT OF ROCKS AND MINERALS FROM CLONCURRY-MT. ISA.

Stratigraphic Position.	Host Rock.	Uranium Mineral.	$\%U_3O_8$
Argylla Series.. ..	" Intrusive " calcite..	Davidite	3·5
Argylla Series.. ..	Lenses of sodic migmatite (?)	Brannerite	31·2
Argylla Series.. ..	Allanite rock amid scapolite granulites	Allanite	Trace to 1·5
Templeton Intrusives	Alaskite	Davidite	3·8
Mount Isa Series ..	Hornfels	Uraniferous magnetite-ilmenite	Trace to 0·43
Mount Isa Series ..	Chloritic quartzite ..	Uraniferous magnetite-ilmenite	Trace to 0·73

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EXPLANATION OF PLATES.

PLATE IV.

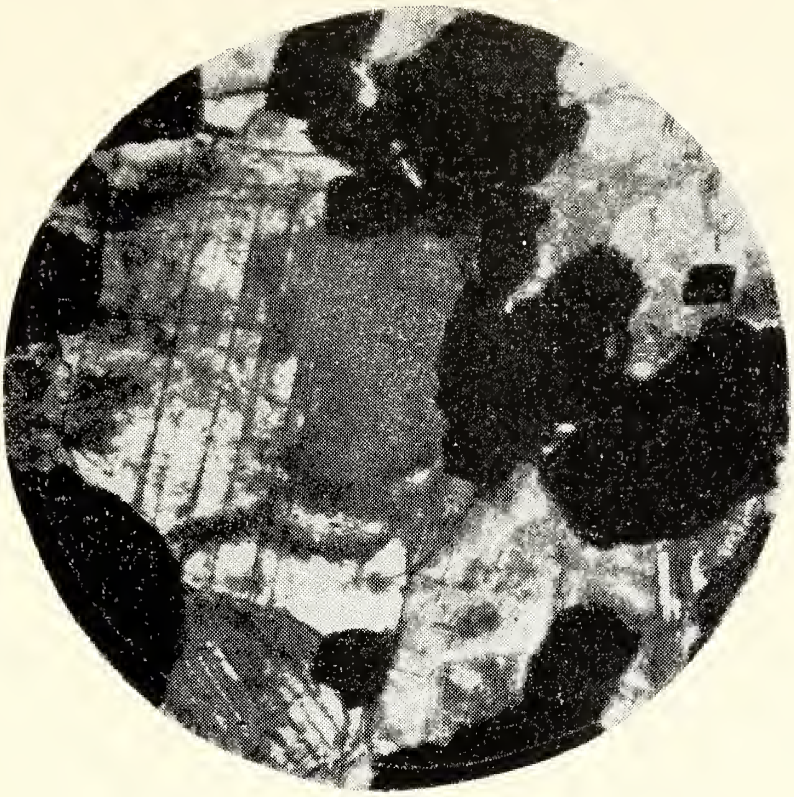
Figure 1.—Davidite replacing orthoclase in alaskite. Six Kangaroos Lease, Cloncurry. Ordinary light, $\times$ 25.

Figure 2.—Allanite rock showing granoblastic allanite (grey) and accessory epidote and allanite (colourless). Mary Kathleen Lease, Cloncurry. Ordinary light, $\times$ 25.

PLATE V.

Figure 1.—Indurated shale (hornfels) showing faulted layer of uraniferous iron ore. Spike Lease, Mt. Isa. Ordinary light, $\times$ 25.

Figure 2.—Slightly metamorphosed chloritic quartzite showing disseminated crystals of uraniferous iron ore. Counter Lease, Mt. Isa. Ordinary light, $\times$ 25.



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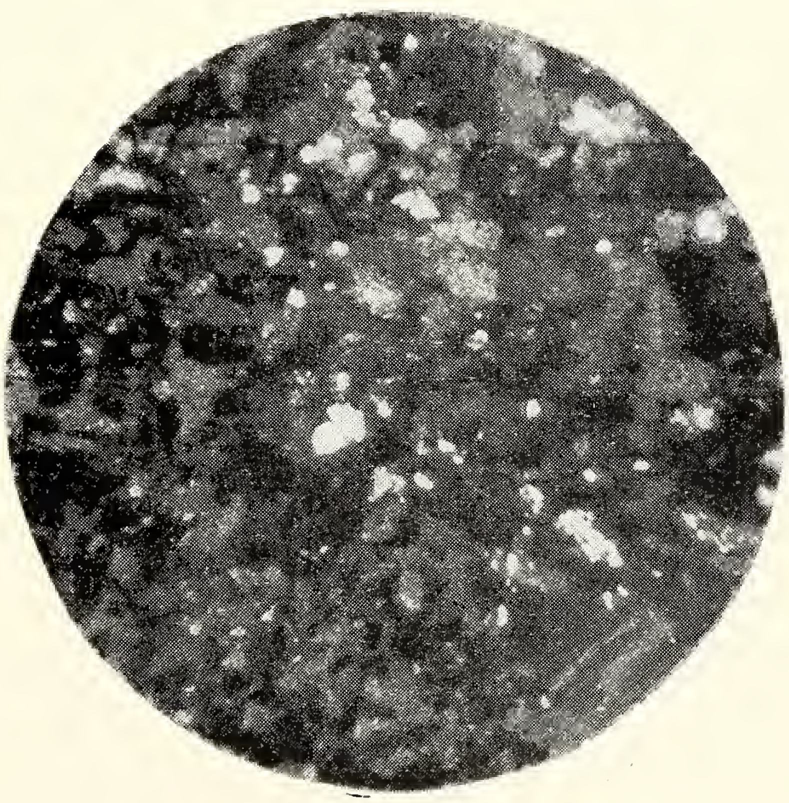

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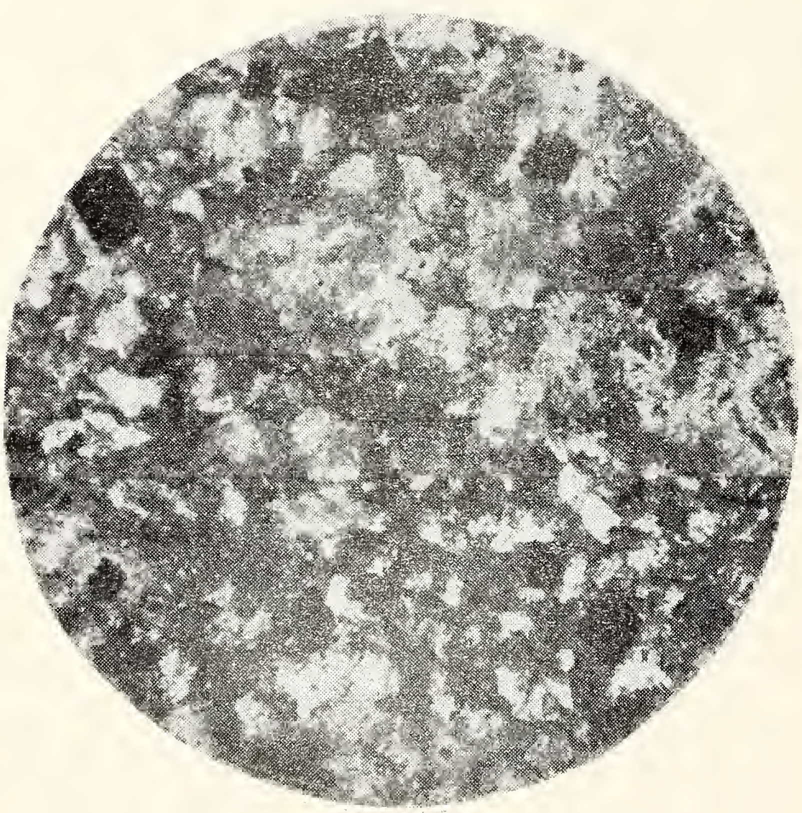

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Vol. LXVI., No. 6.

A NEW LUNG-WORM FROM AUSTRALIAN MARSUPIALS (Nematoda: Metastrongylidae)

By M. Josephine Mackerras, Queensland Institute of Medical Research, Brisbane.

(With one Plate and six Text-figures.)

(*Received* 15*th December*, 1954; *issued separately*, 19*th September*, 1955.)

A new Metastrongylid lung-worm has been found in two species of bandicoots. Five infected individuals of *Isoodon obesulus* (Shaw and Nodder) and one of *Perameles nasuta* Geoffroy were studied. In addition, specimens of the same parasite from *P. nasuta* were received from Mr. A. J. Bearup, School of Public Health and Tropical Medicine, Sydney.

In animals which were autopsied soon after capture, only small, inconspicuous, white nodules were present near the pleural surface of the lung. Within these nodules adult worms were found intricately embedded in the lung substance (Plate VI., fig. 1.) They proved very difficult to extract. However, one animal (*P. nasuta*) was kept in captivity for ten months, during which time it passed large numbers of first-stage larvae in its faeces. At autopsy its lungs were extensively mottled with greyish and white nodules. Many worms were embedded in these nodules, but others were lying more or less free in the bronchioles and extending for part of their length into the bronchi. They could with care be extracted intact. These worms were considered full-grown, being more than ten months old, and the measurements given below were made on them.

Worms were washed in 0·4 per cent. saline, killed with hot 70 per cent. alcohol, and stored in 70 per cent. alcohol containing 5 per cent. glycerine. Measurements of total length were made in the latter fluid; other measurements and photomicrographs were made from specimens cleared in lacto-phenol.

DISTINCTIVE FEATURES.

This parasite may be readily distinguished from *Marsupostrongylus bronchialus* Mackerras and Sandars, from the same hosts. *M. bronchialus* is a much stouter worm which lives in the bronchi. It has a voluminous, strikingly ornamented teguminal sheath. The bursal formula is different, the lateral rays arising from a common base and the dorsals being reduced to papillae. The spicules are also distinct. The new species resembles *Plectostrongylus fragilis* Mackerras and Sandars, from the marsupial mouse, in general body form and location in the lung. However, *P. fragilis* is a smaller worm, distinguishable in the male by the bursa which has the same formula as *M. bronchialus*, and in the female by the sharply pointed tail and relatively muscular ovijector. The spicules are also quite distinct.

It seems better to make a new genus for this parasite rather than emend the definition of either of the above mentioned genera to include it. When our knowledge of the marsupial lung-worms is less fragmentary, it may be possible to reduce the number of genera. All three species from Australian marsupials appear more closely related to each other than to the metastrongyles of the Eutheria, or to those of South American marsupials. They all possess tiny, delicate, complex spicules, which are equal in size and shape, and which split distally into long flexible rods clothed with membrane.

The generic name *Filostrongylus* is proposed, the name being referable to the extremely long, thread-like appearance of the worm. The specific name *peramelis* indicates the hosts, which belong to the family Peramelidae.

Filostrongylus n.g.

Relatively smooth, thread-like worms. Male bursa with short, stumpy rays, ventrals arising separately, laterals also arising separately, externo-dorsal single, dorsals paired. Spicules complex, equal, each splitting distally into rods. Female without muscular ovijector, vulva close to posterior end, ovoviviparous.

Filostrongylus Peramelis n.sp.

Hosts: *Perameles nasuta* Geof. from Mt. Nebo, S.Q., and Sydney, N.S.W., and *Isoodon obesulus* (Shaw and Nodder) from Mt. Nebo and Mt. Glorious, S.Q.

Habitat: Lung substance, bronchioles, bronchi.

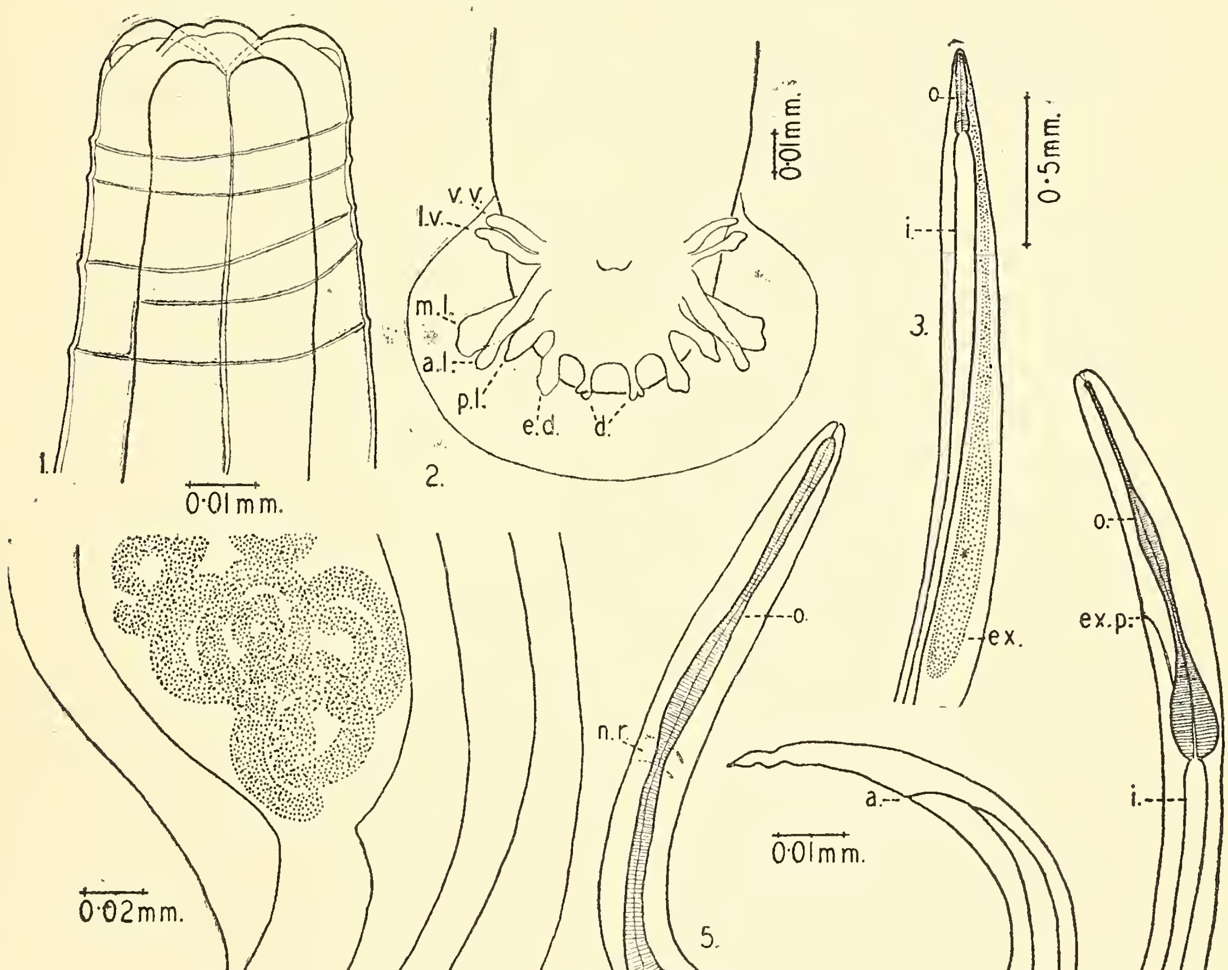
Types: Holotype male and allotype female from *Perameles nasuta*, S.Q., in the collections of the Queensland Museum.

Male: Long, delicate, filiform, tapering at each end, but otherwise nearly uniform in width. Cuticle with fine longitudinal striations; a series of irregular transverse wrinkles present in the oesophageal region (Text-fig. 1). Length, 35 to 49 mm., average of twelve specimens 44.5 mm. Diameter behind head 0.036 mm., at the oesophageal-intestinal junction 0.1 mm., maximum 0.24 mm., tapering to 0.06 mm. at cloaca. Nerve ring about 0.13 mm. from anterior end. The cuticle of the head is raised into three slightly bilobed lips. There are three rather squat papillae *en face;* two of them are shown in Text-fig. 1. Oesophagus 0.26 to 0.28 mm. in length by 0.05 mm. in maximum breadth. It is slightly constricted in the middle, and widest posteriorly. The intestine begins as a wide tube, containing pus cells and epithelial cells mixed with some red cells from the host; it gradually becomes narrower and pushed to one side, first by the excretory sac and then by the gonad. The excretory sac is about 3 mm. long; its opening could not be distinguished (Text-fig. 3).

Bursa small, rays short and stumpy. The ventrals are sub-equal, and lie closely approximated. The laterals arise separately; the antero-lateral and especially the medio-lateral have relatively broad bases, that of the former being medial and only slightly anterior to the latter. The antero-lateral usually lies obliquely across the broad medio-lateral, and projects as a finger-like process above and posterior to it. The postero-lateral is much shorter than the other two. The externo-dorsal is single, short and stumpy, sometimes ending in a papilliform projection. There are paired dorsal rays, each short and bifurcated (Text-fig. 2).

The spicules are tiny, delicate, complex structures. Each consists of a thin, curved, irregular plate, produced proximally into a roughened knob, and splitting distally into two long, flexible rods, of which the posterior is the longer. The ventral parts of the spicular plates are closely approximated (possibly fused) in the midline, and the ventral plate so formed is produced distally into a median pointed piece, studded laterally with minute, short, blunt teeth. The tips of the long rods are clothed with membrane, and may sometimes be seen projecting through the cloaca. Posterior to the rods is a delicate gubernaculum shaped like a flattened gutter (Plate VI., figs. 2-4).

FEMALE: Length 65 to 92 mm., average of nine specimens 81 mm. Diameter just behind the head 0.05 mm., at the oesophageal-intestinal junction 0.14 to 0.19 mm., maximum 0.34 to 0.39 mm., tapering to 0.07 mm. at the vulva. In a specimen measuring 92 mm., the coils of the first ovary began about 3 to 4 mm. from the anterior end and those of the second ovary about 30 mm. from it. The greater part of the body is filled with the two uteri lying parallel with each other, each packed with ova containing well-developed embryos. The uteri unite 0.7 mm. from the vulva to form a common uterus, also packed with ova. This



Text-figures 1-6.—*Filostrongylus peramelis*, n.g., n.sp. 1. Head of male, showing lips, papillae, and transverse cuticular wrinkles; 2. Bursa of male; 3. Anterior end of male; 4. Posterior end of female; 5. First-stage larva; 6. Third-stage larva. a. anus, a.l. antero-lateral ray, d. dorsal rays, e.d. externo-dorsal ray, ex. excretory organ, ex.p. excretory pore, g.r. genital rudiment, i. intestine, l.v. latero-ventral ray; m.l. medio-lateral ray, n.r. nerve ring, o. oesophagus, p.l. postero-lateral ray, v. vulva, v.v. ventro-ventral ray.

is separated from the vagina by a slight constriction. The cuticle lining the vagina is continuous with the teguminal sheath. Tail short, bluntly rounded, anus 0.03 and vulva 0.06 to 0.09 mm. from the tip (Text-fig. 4). Other features as in the male.

LIFE HISTORY.

First-stage Larva: Specimens from the uterus of the female measured 0.225 to 0.245 mm. in length by 0.011 mm. in width. There is a short oral cavity leading into a rhabitoid oesophagus measuring 0.1 mm. by 0.008 mm. at the bulb. Nerve ring 0.055 to 0.06 mm. and genital rudiment 0.144 mm. from the anterior end. Anus 0.03 mm. from posterior end. The tail is slender, pointed, and notched dorsally and ventrally (Text-fig. 5).

TABLE 1.

Attempts to Infect Bandicoots with *F. peramelis*.

Number of Recipient.	Date of Attempted Infection.	Dose of Larvæ.	Results.
360	(1) 1–2–54	10	–
	(2) 19–2–54	32	–
	(3) 23–4–54	40	–
362	(1) 19–2–54	45	+*
	(2) 30–4–54	48	+
364	17–5–54	54	+*
365	25–5–54	30	–
367	(1) 26–10–54	6	+
	(2) 1–11–54	2	
	(3) 5–11–54	12	

* Infection died out in a few weeks.

First-stage larvae penetrated the foot of the small, dark, garden slug, *Agriolimax laevis* Muller, and went through developmental stages closely resembling those of other known lung-worms. The larvae became curled in a circle, and absorption of food material resulted in the intestinal cells becoming loaded with refractile granules. Full-growth first-stage larvae were about 0.4 mm. in length by 0.026 mm. in width. The first moult occurred in about two weeks, and the second about one week later. The third-stage larva remained within the two cast skins.

Third-stage Larva: Length 0.45 mm. by 0.022 mm. in breadth. There is a short oral cavity leading into a rhabitoid oesophagus. There are two, rather delicate, chitinous rods with knobbed ends at the beginning of the oesophagus. The oesophageal bulb is well-developed, and appears dark by transmitted light. Oesophagus 0.135 mm. long by 0.015 mm. in maximum diameter. The excretory pore lies about 0.086 mm. and the genital rudiment 0.28 mm. from the anterior end. Tail 0.035 mm. long, sharply pointed.

It is unlikely that *Agriolimax laevis,* which is probably an introduced slug, is a natural host for this parasite. Many larvae failed to penetrate the slug, or, if they did, failed to reach third stage. Others succeeded in developing fully, but were rapidly walled around by fibroblasts and eventually absorbed. Many apparently normal third-stage larvae may not have been viable, as it proved difficult to set up new infections.

The slug infections were so light that it was never possible to get large numbers of larvae. Several attempts were made to transmit the infection by feeding third-stage larvae to *Isoodon obesulus*, which had been held in captivity for some months, and repeatedly examined for first-stage larvae to exclude the possibility of a pre-existing infection. The results of these experiments are set out in Table 1.

The prepatent period, that is, the interval between feeding infective material and the appearance of first-stage larvae in the faeces, was between six and seven weeks.

SUMMARY.

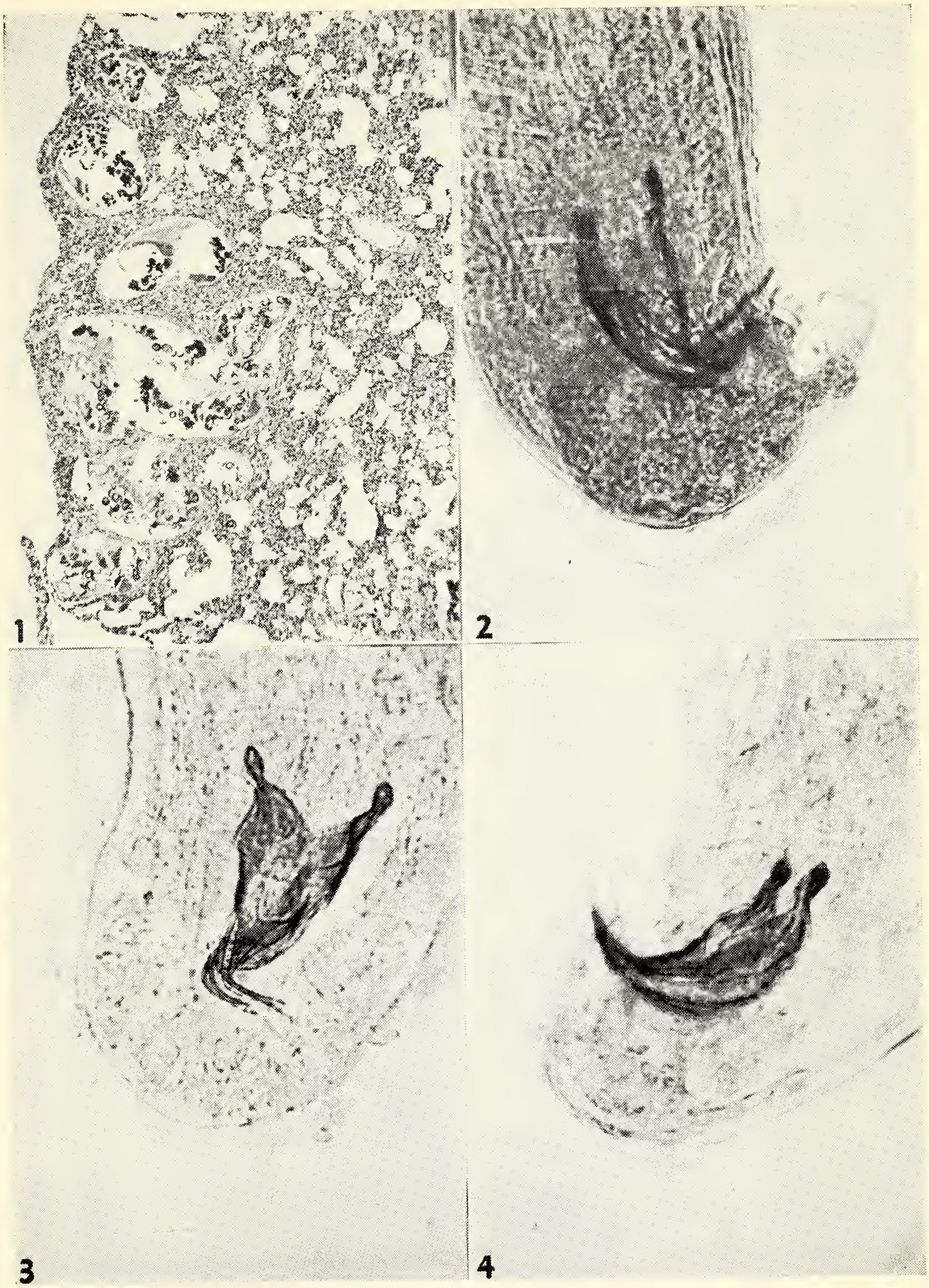
Filostrongylus peramelis n.g., n.sp., is described from the bronchioles of the bandicoots, *Isoodon obesulus* and *Perameles nasuta.*

Development of this parasite occurred in the slug, *Agriolimax laevis,* in about three weeks. Four clean bandicoots were infected, the prepatent period in them being between six and seven weeks.

EXPLANATION OF PLATE VI.

Figure 1.—Section of lung of *Isoodon obesulus,* showing female worm coiled up near pleural surface, x 32.

Figures 2-4.—Three successive views of tail of male worm in right ventro-lateral, ventral and left lateral aspects respectively, showing spicules, x 384.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Vol. LXVI., No. 7.

MEMORIAL LECTURE.

HEBER ALBERT LONGMAN.

By D. A. Herbert, Department of Botany, University of Queensland.

(With one Plate.)

(*Delivered before the Royal Society of Queensland 29th November,* 1954.)

Two years before his death in February 1954, the Australian and New Zealand Association for the Advancement of Science conferred the Mueller Medal on Heber Albert Longman for his distinguished services to natural science in Australia. By a curious coincidence the two scientists, one whose memory was honoured by the establishment of the medal and the other on whom it was conferred, had each come to Australia at the age of twenty-two for health reasons. Both, after an initial period at other employment, turned to botanical science as their main interest. Baron von Mueller achieved world renown as a botanist, but Mr. Longman was to achieve his greatest distinction in the field of palaeontology.

Heber Longman had little science training beyond the basic introduction of his schooldays, but the history of Australian science is liberally sprinkled with the names of men who, keen amateurs in their youth, have developed their talents without the help of the short-cuts of a formal University education in the field of their specialization. The village of Heytesbury, where he was born on June 24th, 1880, lies on the edge of the Downs in Wiltshire, a few miles from the market town of Warminster. In the library of his father, the Rev. F. Longman, a Congregational minister of liberal views and wide interests, his browsing laid the foundations for his life-long literary interests. Wiltshire is famous for its antiquarian relics, and he developed an early interest in the archaeology of the surrounding country. Stonehenge, the camp of Vespasian near Amesbury, and the castle ruins at Old Sarum were not far away. The science masters at his school, Emwell House in Warminster, encouraged his natural leanings towards botany, geology and archaeology. His early environment was full of opportunity for a young naturalist, but another important consideration decreed that his talents should be developed far from these congenial surroundings.

Though to all appearances a strong boy with some reputation as a soccer player, he was constitutionally delicate, and was advised to come to Australia on account of chest weakness. His family doctor suggested Toowoomba. He knew no one there, but his sisters in England had insisted that he should make himself known to the Congregational minister. He arrived in Toowoomba in 1902, and duly called on the Rev. J. M. Bayley, whose daughter Irene became Mrs. Longman in 1904.

Toowoomba, with the mists of the Range, did not have the climate best suited for his chest weakness. In fact, the trouble became more distressing. It was not until years later when he came to Brisbane that he got the relief he sought. In the meantime, however, he spent nine active years in the garden city. There he married, and there he continued to pursue his interests in literature and natural history. Nor did he forget his soccer; he introduced the game to Toowoomba.

When he arrived, a small weekly newspaper had just closed down, and its plant was for sale. He bought it and engaged a printer. Though he knew no one in the Toowoomba business world, he canvassed for advertisements and in a few weeks the first copy of the *Downs Post* appeared. It was a small local weekly paper similar in function to the suburban newspapers of the present day. It must have required some versatility and energy on the part of one whose only acquaintance with journalism had been the writing of an occasional article. But hard work never worried him; he soon was able to set up the old-fashioned hand type and even take the ancient printing press to pieces and put it together again when it refused to work. Often the editor would hand-set the type of his report on an evening meeting or concert before he went to bed, and leave it ready for the printer to run off next morning.

A freshness about the presentation of reports, news items and literary and social comments attracted the attention of Toowoomba people, and before long a small company of business men was formed. The little news sheet evolved into a weekly paper called *The Rag* by George Essex Evans, the Queensland poet who became Editor with Heber Longman as sub-editor and manager. This lively publication created much interest beyond local circles and was much quoted at the time. When Essex Evans later retired to his farm below the Range Longman carried on as Editor, but with his English respect for propriety, he changed the name to *The Citizen*. Bound copies of these papers are now in the possession of the Toowoomba Historical Society.

In 1908 he started sending botanical specimens to F. M. Bailey, the Colonial Botanist in Brisbane. A letter signed by Bailey, but written by his grandson, young Cyril White, named a couple of specimens and told him that, though he often received specimens from Toowoomba he did not know of any regular collectors in the district. It seemed that there were no local botanists, so Longman set about building his own collection and getting it named by the Colonial Botanist or by J. H. Maiden, the Government Botanist in Sydney. One of his finds, *Sarcochilus longmanii*, was named in his honour. His herbarium, with additions from Brisbane and the north coast, was later presented to the Royal Botanic Gardens, Kew.

Heber Longman initiated the Field Naturalists Club in Toowoomba, his own special interest in those days still being in plants. Another member was Dr. Ronald Hamlyn Harris, a zoologist trained in Germany, who had worked for some time in the West Indies, and was then teaching at the Toowoomba Grammar School. Hamlyn Harris later succeeded De Vis as Director of the Queensland Museum, and he persuaded Longman to come to Brisbane to join his staff in 1911.

In 1917, when Hamlyn Harris resigned, Longman was appointed Director. He was still an ardent botanical collector, going out on excursions in his holidays and week-ends with his vasculum and a milk can. The vasculum was a mystery to country folk, but it was the milk can that really aroused their curiosity.

His interests were now gradually directed away from botany, though he published some papers of special interest, including a list of plants of Masthead Island compiled by him on the first University of Queensland biology excursion, under the leadership of Professor T. Harvey Johnston. He published over seventy papers, mostly in the *Memoirs of the Queensland Museum*, and his really notable contributions were in the field of vertebrate palaeontology. He described, among others, two dinosaurs (*Rhoetosaurus brownei* and *Austrosaurus mckillopi*), cretaceous marine reptiles (*Cratochelone* and *Kronosaurus*) a cretaceous fish (*Flindersichthys*) and a marsupial, *Euryzygoma*. These were new genera. *Kronosaurus queenslandicus* was reconstructed with remarkable accuracy from a mandible with incomplete dentition. It is a matter of great regret that when a skeleton was finally discovered by an American collector it went to the United States.

The work on these fossil bones was very onerous. Not much time was available from the multitudinous routine tasks that devolve on a museum director. His annual three week vacations were given to collecting fossil bones, where formerly they were spent in plant collecting. Long evenings and week-ends were spent in chipping away the matrix and in studying the revealed structures. Almost the whole of one Christmas Day was spent with Mrs. Longman in working on the *Euryzygoma* material. But the results of this work were of great value to Queensland palaeontology, and it was this that won him wide recognition.

Sir John Goodwin, when he was Governor of Queensland, spent a great deal of time at the Museum. He was keenly interested in natural history but had a special professional interest in osteology. On one occasion when he was receiving guests officially at a levee he slipped his hand in his pocket and when he shook hands with Longman pressed a bone into his palm. ''You'll be interested in this, Longman'', he said and then resumed his gubernatorial duty of greeting the next guest. Sir Matthew Nathan, who was Sir John's predecessor, had also been a regular visitor to the Museum, though perhaps more in connection with the Great Barrier Reef committee, and very closely associated with the organization of the Yonge Expedition, as well as making his own contributions to the study of reef fauna.

Longman's exhibits at meetings of the Queensland Naturalists' Club and the Royal Society were a regular feature of their meetings, and natural history observations were as likely to be expounded as were the more abstruse points of the anatomy of an aboriginal skull or a fossil bone. Members were never certain whether they were going to be charmed by the beauty of a rare sea-shell or startled by a live snake. He had the happy power of investing the most unlikely looking specimen with an absorbing interest. The secret lay in his own obvious enjoyment in communicating and sharing his own enthusiasm for the subject he was discussing.

Naturally his services were in great demand for broadcasts and public lectures, the latter not only at the museum, but at meetings of societies and organizations often with no specific interest in natural science. Whether it did any permanent good in many cases is debatable, but his lectures to school children, particularly during the bird month of October, resulted in the signing of tremendous numbers of Nature Lover's certificates, and no doubt had a good effect in helping to build up a public attitude towards the protection of the native fauna. At the other end of his range of lecturing duties was the course in Vertebrate Palaeontology that he gave to geology students in the University of Queensland.

Original research in natural history included papers on that beautiful spider, *Dicrostichus magnificus*. I spent an evening in his garden when he lived in Wooloowin watching this remarkable creature catching night-flying moths. It was an amazingly skilful performance repeated, I suppose nightly in thousands of gardens, but a habit likely to be discovered only by someone with the keenest powers of observation.

Mrs. Longman's part in many of these researches was important though unostentatious. She was a trained teacher, and had an independent career of great distinction in the public life of Queensland. She was president of the National Council of Women from 1921 to 1925, and took a leading part in child welfare and educational activities. She was the first woman member of the Legislative Assembly in Queensland, holding the Bulimba seat from 1929 to 1932. In the early days in Toowoomba she had worked on the weekly newspaper with her husband. She went on the collecting trips that were their form of relaxation, and spent long hours in the evenings and week-ends at the Museum helping with the tedious task of preparing the vertebrate fossil material. The paper on the spider *Dicrostichus* was the result of husband and wife collaboration. Their home was the meeting place of the wide circle of friends and visiting scientists with whom their common and diverse interests were intertwined.

For many years a group of kindred spirits, the Philosophy Circle, met regularly at the rooms of Dr. C. A. Thelander on Wickham Terrace. There, in an atmosphere of friendliness, violent argument and tobacco smoke, they were prepared to discuss anything—the origin of life, war and peace, water divining, education, religion, literature, psychology, philosophy or politics. The circle included in its membership clerics and rationalists, medical and business men, scientists and journalists of such diverse outlooks that there was rarely any doubt that the discussion, even if it might be inconclusive, would be lively and uninhibited. Longman had an ardent admiration for T. H. Huxley, and that great biologist had a tremendous influence on his whole biological and philosophical outlook. There is no doubt that members sometimes deliberately chose subjects on which the debate could be diverted to the classical nineteenth century battle ground of science and religion, and on such occasions Father Little and Longman, two firm friends, would go happily into the combat. We were soon back in the stormy controversial days of another period in the history of biology. The other members if they were not in the fight waited with academic detachment while St. Thomas Aquinas on the one hand and Thomas Henry Huxley (beatified as St. Thomas Huxley by those who had heard this type of controversy on many occasions) on the other, were quoted at length. The implacable opponents were quite likely to share one another's matches and tobacco when the unsettled argument moved to the supper table.

Years later, in 1953, Thomas Henry Huxley's grandson, Dr. Julian Huxley, paid a brief visit to Brisbane and called on Longman, then in retirement at his home at Chelmer. It was not a courtesy visit to a stalwart admirer of his grandfather, but an eminent biologist paying his respects to a colleague who had made distinguished contributions to biology in another land.

There was another group in which he took a special interest, the Thirty Club. It met under more formal conditions than the Philosophy Circle, with its deliberations centred round a paper prepared by one of the thirty members on any chosen subject, preferably controversial. Discussion was on a different plane from that of the Philosophy Circle. It opened with two carefully prepared criticisms after which the debate continued well into the night. Longman's contributions, whether prepared or extempore, were sprinkled with quotations from his wide range of reading, and reflected his long-established habit of making written notes of passages that had impressed him by reason of their literary style or the ideas they presented. This in fact was his general practice at meetings of the Royal Society and elsewhere, and was a habit that if more widely adopted would add considerably to the interest of scientific meetings.

For many years he was an active member of the Rationalist Press Association of Great Britain, and about eleven years ago was elected to the limited and distinguished list of its honorary associates. Here he was in the company of such eminent savants as Edouard Heriot, Albert Einstein, J. B. S. Haldane, Julian Huxley, Sir Macfarlane Burnet, Bertrand Russell and W. K. Gregory. Though he took a keen interest in the local Rationalist Society in its earlier and more philosophical phase, his connection ceased when it became political and extreme.

He was essentially a humanist. Brought up with a strong traditionally religious background and at the same time deeply imbued with the biological attitude of the post-Darwinian period, he evolved his own religious philosophy as expounded in his book *The Religion of a Naturalist,* published in 1914. He did not try with missionary zeal to force his opinions on others, and indeed some of his best friends held very diverse views. Naturally, of course, he corrected their misconceptions frequently and vigorously, but probably would have lost much of the enjoyment of life if they had come round to his views. His faith crystallized from his study of biology. It was greatly influenced by the writings of T. H. Huxley and was canalized by such later writings as those of the mechanistic biologist Jacques Loeb. It did not involve the summary discarding of the teachings of his earlier days. These remained with him as part of his life, as our early teachings must, however much they are modified in external form by time and circumstance. His faith took a different, and to him perfectly satisfactory form, freed from the supernatural and without expectation of reward or fear of punishment beyond this life.

Longman was a leading supporter of the Royal Society of Queensland. He was twice President, in 1919 and 1939, and for twelve years was editor of the Journal and Proceedings. He has been President of the Queensland Naturalists' Club, Vice-president of the Great Barrier Reef Committee, a Fellow of the Linnaean Society of London and of the Royal Anthropological Institute, and a Corresponding Member of the Zoological Society of London. In 1946 he was awarded the Australian Natural History Medallion, and in 1952 the President of the Royal Society of Queensland at a meeting of this Society presented him with the coverted Mueller Memorial Medal, awarded by the Australian and New Zealand Association for the Advancement of Science for his outstanding contributions to palaeontology in Australia.

In 1945 he relinquished the Queensland Museum directorship, having reached the retiring age of 65. The last year or so had been very difficult and trying on his health. The Museum had always been short of scientific workers and the position became much worse during the war. Many of the staff were seconded for war-time work and the extra work and worry took great toll of his strength. He was a very sick man when at last he was able to retire and was for some months in the constant care of his medical adviser. Rest and freedom from worry, however, restored him to better health.

His reading was as omnivorous as ever. In his riverside home, ''Cotley'', at Chelmer, he was surrounded by the books of the library he had accumulated down the years. They reflected his wide interests in science, history, philosophy, biography, great literature, drama and, not least amongst them, poetry. In the spacious garden were the birds, the trees and shrubs with their seasonal changes and all the minor tenants that had always interested him.

Though he gradually withdrew from the various organizations that had been so much part of the life of his physically vigorous days, he now reached a wider audience through his writings. He contributed a regular column to the *Courier Mail* on Nature's Ways, which had a great following throughout Queensland. It is a matter of regret that these excellent articles, based on over forty years of experience, were of such an ephemeral nature.

He passed away on 16th February, 1954.

Heber Albert Longman.

The Royal Society of Queensland

Report of the Council for 1953

To the Members of the Royal Society of Queensland.

Your Council has pleasure in submitting the Annual Report of the Society for 1953.

General meetings have been held in the lecture theatre of the Physiology Department of the University of Queensland, William Street, and the thanks of the Society are due to Professor W. V. Macfarlane and his staff for their co-operation and hospitality. Council meetings have been held in the University, George Street, for which appreciation is expressed to the Registrar.

Ten meetings were held during the year, including one special meeting. Six addresses were given and two meetings were devoted to papers and exhibits.

A special meeting was called to consider the financial position of the Society relative to the increased costs of publication. Rules 11 and 12 were revised to allow an increase in subscriptions effective from January, 1954.

Following an application to the Postmaster-General's Department, the Proceedings have been registered as a periodical, thus effecting a considerable saving in postage.

Mr. S. T. Blake and Miss D. F. Sandars were appointed delegates for the Society to the Council of A.N.Z.A.A.S., and Dr. P. S. Hossfeld was nominated as the representative of the Society at the Special Centennial Meeting of the Royal Society of South Australia.

Four papers were accepted for publication in Volume LXV. (1953) of the Proceedings and are in the hands of the printer. Volume LXIII. (1951) has been issued and it is expected that Volume LXIV. (1952) will be issued in the near future.

During the year there were 2,124 additions to the Library and 22 new exchanges were established. The Library has been moved to the Administration Block of the University, George Street.

The Council records with regret, the following deaths: L. F. Hitchcock, M.Sc., a member, who died in May, 1953; R. Hamlyn-Harris, D.Sc., F.R.M.S., F.L.S., F.R.E.S., a past member, who died in June, 1953; F. G. Gipps, an honorary life member, who died in September, 1953; A. H. Marks, C.B.E., D.S.O., M.D., a past member, who died in January, 1954; and H. A. Longman, F.L.S. an honorary life member, who died in February, 1954.

There are now 6 honorary life members, 1 corresponding member, 9 life members, 218 ordinary members and 3 associate members of the Society. During the year the Society lost 3 members by death and 10 by resignation; the names of 7 members were removed for arrears; one honorary life member (E. H. Gurney) and 7 ordinary members were elected.

Attendance at Council Meetings was as follows:—S. T. Blake, 8; I. M. Mackerras, 6; M. Shaw, 7; D. F. Sandars, 6; K. Robinson, 6; E. N. Marks, 8; G. Mack, 7; F. S. Colliver, 9; A. R. Brimblecombe, 5; T. K. Ewer, 8; B. Howard, 6; F. T. M. White, 3; G. L. Wilson, 4.

Mr. L. P. Herdsman has again acted as Honorary Auditor. To him the sincere appreciation of the Society is expressed.

S. T. BLAKE, President.

DOROTHEA F. SANDARS, Hon. Secretary.

KATHLEEN ROBINSON, Asst. Hon Secretary.

THE ROYAL SOCIETY OF QUEENSLAND.

STATEMENT OF RECEIPTS AND EXPENDITURE FOR YEAR ENDED 31st DECEMBER, 1953.

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance in Commonwealth Bank 31/12/52	575	4	10			
Cash in hand 31st December, 1952 ..	9	4	6½	584	9	4½
Subscriptions—						
1953 Membership	236	17	6			
Arrears	73	4	6			
Advance	3	15	0	313	17	0
Commonwealth Loan Interest	10	0	0			
Commonwealth Savings Bank Interest ..	15	4	9	25	4	9
Sale of Reprints and Society Proceedings	..			76	1	5
Exchange	..			0	16	6
				£1,000	9	0½

EXPENDITURE.

	£ s. d.	£	s.	d.	£	s.	d.
Government Printer—Payment Vol. LXII. (1950)		611	5	0			
Less Amount paid in 1952 ..	300 0 0						
Government subsidy ..	199 19 6	499	19	6	111	5	6
Government Printer — Part Payment Vol. LXIII. (1951)		..			240	0	0
Government Printer — Part Payment binding 67 library volumes ..		..			77	0	0
Library Insurance		..			1	18	5
Purchase, missing parts, Review of Applied Entomology		..			4	0	1
Transport, volumes donated to library ..		..			4	12	0
Stamps, &c., Secretary		21	15	9			
Treasurer		1	0	2			
Librarian		22	7	9½	45	3	8½
Supper		..			6	19	0
Stotts—Addressograph plates, &c. ..		..			13	16	8
Stationery—Envelopes		19	5	6			
Duplicating paper		13	10	0	32	15	6
Balance in Commonwealth Bank 31/12/53		..			454	13	10
Cash in hand 31st December, 1953—							
Secretary		6	3	7½			
Treasurer		0	7	2½			
Librarian		1	13	6	8	4	4
					£1,000	9	0½

The total amount due to Government Printer for Vol. LXIII. is £480 8s. 9d., and for binding Library volumes, £155 18s. 3d.; payment of balance awaits advice of amount of Government Subsidy. In addition to the credit balance shown in the above statement, the Society holds the following Capital funds—

Commonwealth Loan	£320
Savings Certificates	2
	£322

held in safe custody by the Commonwealth Bank of Australia, Adelaide street, Brisbane.

[Signed] ELIZABETH N. MARKS, Hon. Treasurer.

Examined and found correct.

[Signed] L. P. HERDSMAN, Hon. Auditor.

5th March, 1954.

Abstract of Proceedings, 29th March, 1954.

The Annual General Meeting of the Society was held in the Physiology Department of the University of Queensland on Monday, 29th March. Forty-two members and friends were present. The minutes of the last Annual Meeting were confirmed. The Annual Report was adopted and the Balance-sheet received. A recommendation of Council was adopted that the following, having been members for over thirty-five years or having given meritorious service to the Society or to science within this State, should be made Honorary Life Members: Dr. F. Bage, Dr. M. J. Mackerras, Professor W. H. Bryan, Mr. A. P. Dodd, Dr. E. O. Marks, Mr. S. N. Watkins. Mr. K. McDonald and Dr. S. Crawford were elected to Ordinary Membership; Mr. D. Kronfeld and Mr. E. Broadhurst were nominated for Ordinary Membership; Miss I. Keleher, Miss D. Holt, Miss V. K. Hedges were nominated for Associate Membership.

The following members were elected as Office-Bearers for 1954:—President, M. Shaw; Vice-President, A. L. Reiman; Hon. Secretary, T. K. Ewer; Assistant Hon. Secretary, B. Howard; Hon. Treasurer, E. N. Marks; Hon. Editor, G. Mack; Hon. Librarian, F. S. Colliver; Councillors, A. R. Brimblecombe, I. M. Mackerras, D. F. Sandars, F. T. M. White, G. L. Wilson; Hon. Auditor, L. P. Herdsman.

The Presidential Address, entitled "Some Pioneers in Plant Exploration and Classification," was delivered by Mr. S. T. Blake.

Abstract of Proceedings, 4th May, 1954.

The Ordinary Monthly Meeting of the Society was held in the Physiology Department of the University of Queensland on Tuesday, 4th May. About twenty-three members and friends were present. The Minutes of the previous Ordinary Meeting were confirmed. Mr. D. Kronfeld and Mr. E. Broadhurst were elected to Ordinary Membership; Miss I. Keleher, Miss D. Holt and Miss V. K. Hedges were elected to Associate Membership.

Assistant-Professor G. Smith delivered an address entitled "The Part Played by Industry and Allied Sciences in the Rise of Agricultural Production in U.S.A." He said that in the U.S.A. agricultural production had been greatly boosted by the service of science and industry. In particular he dealt with the New England region, where there is about 50 inches of rain equivalent, quite well distributed throughout the year, and a podzol type of soil. The growing season ranges from about 90 days at the Canadian border up to 150 days in southern New England. The six New England States (Maine, Vermont, New Hampshire, Massachusetts, Connecticut and Rhode Island) have a land area of about one-tenth that of Queensland, but a population of 9.3 million.

Plant scientists have made outstanding contributions in the development of new varieties, such as landino clover, and research in soils and fertilizers has resulted in farmers applying about three times as much fertilizer in 1953 as in 1940. Greater mechanization has made it possible to produce a better-quality product with a smaller labour force. Increased animal production was much indebted to the recent contributions of pharmacologists. The application of antibiotics, both in the treatment of clinical disease and as a feed supplement, was resulting in increased life-time production in dairy cows, faster growth in pigs and poultry, with decreased morbidity and mortality in all farm livestock. In 1937, the average production was 7,665 lb. milk and 297 lb. butterfat, while in 1952 it increased to an average of 8,472 lb. milk and 349 lb. butterfat.

Abstract of Proceedings, 31st May, 1954.

The Ordinary Monthly Meeting of the Society was held in the Physiology Department of the University of Queensland on Monday, 31st May. Forty-five members and friends were present. The Minutes of the previous Ordinary Meeting were confirmed.

An address on ''The Investigation of the Problem of Frozen Storage of Meat'' was given by Mr. A. Howard, Dr. H. L. Webster and Dr. R. Lawrie.

Mr. A. Howard made a comparison between frozen and chilled beef. He pointed out that tests had shown that both chilled and frozen beef had similar palatability, that chilled beef was more tender, but frozen beef had better appearance. The problem of ''drip'' had to be overcome in the marketing of frozen beef and it has been shown experimentally that very rapid freezing, leading to the formation of very small ice crystals in the fibres, resulted in much less ''drip'' on thawing. However, in practice, at Cannon Hill, while use of a blast freezer had reduced freezing time from seven days to twenty-four hours, it had been found that this was too slow to reduce ''drip'' significantly. When the pH of beef is kept above 6·0 there is a great reduction in ''drip'' and the speaker outlined the co-operative researches developed between the Low Temperature Station at Cambridge and the Cannon Hill Laboratory in Brisbane on this aspect of the problem.

Dr. H. L. Webster reviewed the chemical changes which occur in muscles after death. Rigor mortis occurs more quickly with high temperatures and is more intense and the pH very low when glycogen reserves are either abnormally high or low. The work of Marsh in New Zealand with homogenized muscle, to which adenosine triphosphate was added, leading to an increase in the gel volume, was mentioned, and the development of this work by Bendall at Cambridge was discussed. Bendall used thin muscle bundles in a bath and made careful records of what happened when various components of muscle were added. The importance of magnesium ions, adenosine triphosphatase, and myokinase was demonstrated.

Dr. R. Lawrie described a more physiological approach to the problem, mentioning in turn—attempts to influence pH; controlling the breakdown of adenosine triphosphate; and ways of producing pre-rigor freezing. He said that, while starvation in rabbits for twenty-four hours resulted in a pH of 6·2 after slaughter, instead of a normal pH 5·9; when bullocks were starved for periods up to twenty-eight days there was no increase in pH in the longissimus dorsi (representing some of the best cuts of beef). Similarly, while pre-slaughter exercise of rats brought a rise of pH from 6·4 to 7·24 post mortem, exercising bullocks for one and a half hours before slaughter had no effect at all. The glycogen reserve in muscle appeared to be much higher in ruminants than in experimental animals. It had been possible to raise the pH of beef muscle by depleting the glycogen reserves by injecting insulin, but the cost of this was prohibitive. These experiments and others in which the control of the rate of breakdown of the Marshall-Bendall enzyme system was attempted by giving magnesium sulphate, together with the failure of blast freezing for beef carcases, emphasised that results obtained with laboratory animals could not be translated into practical measures in an abattoir.

Abstract of Proceedings, 28th June, 1954.

The Ordinary Monthly Meeting of the Society was held in the Physiology Department of the University of Queensland, on Monday, 28th June. Thirty-one members and friends were present. The Minutes of the previous meeting were confirmed. The following members were elected:—Miss M. B. Wilson, Miss N. L. Lavis, Miss E. J. Teys, Mr. L. Pedley, Professor G. H. Russell, Mr. W. F. Ridley to Ordinary Membership; and Mr. P. B. Wallis to Associate Membership. Miss M. Gilmartin was nominated for Ordinary Membership. The Librarian reported that there had been 87 additions to the library.

Professor J. F. A. Sprent exhibited three trematode (fluke) parasites of cats, not previously recorded from Australia. Their specific determination awaits comparison with Japanese species.

Mr. P. J. Skerman exhibited a series of colour slides which demonstrated the recent successful conservation of many thousands of tons of sorghum silage in pits in the western sheep country of Queensland. The important points were (i) these methods are only likely to be successful in the high-clay-content black soils of the State; (ii) bare fallow must be maintained to obtain maximum moisture storage; and (iii) all operations must be fully mechanized to reduce unit cost of the final product.

Dr. M. J. Mackerras and Miss D. F. Sandars exhibited a series of coloured slides and microscope preparations showing certain stages in the life-cycle of a recently discovered rat lung-worm, *Angiostrongylus cantonensis* (Chen.) Larvae are found in the faeces of infected rats and the slug *Agriolimax laevis* (Muller) serves as intermediate host. Migration of third-stage infective larvae to the brain of the rat follows with two moults occurring there. No damage appears to be done to the brain. Between the twenty-eighth and thirty-first day the worms return to the heart in the venous circulation and so reach their final location in the pulmonary arteries.

Dr. E. N. Marks exhibited a bird-fly *Ornitheza metallica* (Schiner) from an aviary budgerigar. The fly is a widespread old-world species found on many different birds and may be a normal parasite of the budgerigar. There is only one previous record of it from Australia, from a fly-catcher taken near Ravenshoe, N.Q. The fly, when captured, had attached, near the top of its abdomen, a female mite surrounded by a cluster of eggs. Slides of the mite (*Myialges caulotoon* Schiner) and eggs were exhibited. This is the first record of a hyperparasitic mite taken on parasitic hippoboscid flies in Australia. Males of these mites are unknown and it has been suggested they will be found on birds. These is some question whether the mites are true parasites of the flies or use them as a means of transport from one bird to another.

Mr. J. T. Woods exhibited a series of vertebrate fossils prepared with the aid of dilute acetic acid. The discovery that a fifteen per cent. solution of acetic acid removes the calcareous matrix of many fossil bones, without attacking the phosphates of the bone, has been of great assistance to palaeontologists.

Dr. G. C. Kenny exhibited a cast of the restoration of the Piltdown skull and outlined the history of the discovery of the various remains. He related that he was working in Professor Le Gros Clark's laboratory at Oxford at the time of the discovery, last year, that the mandible and parts of the skull were faked. He showed how micro-chemical analyses of various parts of the skull, particularly for their fluorine content, revealed marked differences, some parts having a similar composition to other mammalian bone fragments of Pleistocene times, while others were of very recent origin. Chrome salts had been used to give the appearance of age.

Abstract of Proceedings, 26th July, 1954.

The Ordinary Monthly Meeting of the Society was held in the Physiology Department of the University of Queensland on Monday, 26th July. Twenty-four members and friends were present. The minutes of the previous meeting were confirmed. Miss M. Gilmartin was elected to Ordinary Membership and Miss E. Marks, Dr. H. Winter and Mr. H. N. Paine were nominated for Ordinary Membership. Professor Wilkinson was appointed the Society's representative on the Arthur Groom Memorial Fund Committee. The meeting resolved "that A.N.Z.A.A.S. shall continue to similar relationship with the Academy of Science as it has hitherto with the National Research Council."

An address entitled "Problems of Sugar-cane Production: Progress Overseas and in Queensland" was given by Mr. N. L. King. In attempting to place Queensland's production in a world perspective, he said that in size Queensland's sugar industry was fourth behind those of Cuba, India and Brazil. Because of variation in the length of the growing season efficiency could best be assessed in terms of production in "pounds of sugar per acre per month of growing season." On this basis, the production of some leading countries was as follows: Hawaii, 803; Queensland, 586; Puerto Rico, 438; The Philippines, 422; and Cuba, 328. In Hawaii most of the sugar-cane was grown under irrigation or received 250-300 inches of rain per year. Queensland's production figure was attained, except for a very small area in the lower Burdekin delta, under non-irrigated conditions and with a lower rainfall. Where sugar-cane was irrigated in Queensland production rose to an average (in the 1953 season) of 978 lb. of sugar per acre per month. This indicated the potentialities of sugar production in Queensland under irrigation.

In presenting his impressions of a recent world tour he said that in Hawaii, with yields of 100 tons of cane per acre, field efficiency was high. On the other hand, costs were high, and Hawaii could not compete on a free world market. Over one and a-half million dollars were invested per year in research. Recent developments included the use of maleic hydrazide to prevent flowering, and foliar analysis for revealing fertilizer requirements. In Louisiana, U.S.A., it had once been impossible to undertake breeding studies because of the cold winters, but by putting cane into glasshouses for a period, it was now possible to obtain flowers for breeding work. In Florida, the sugar industry was concentrated on peat soils often ten feet deep. Here, drainage was necessary and there were deficiencies of manganese, boron, zinc and copper. In Columbia, South America, sugar-growing was concentrated in the valley of the Cauca River, at an altitude of about 3,000 feet above sea level. The soil is so rich that, although sugar-cane has been grown for about 80 years, it is still producing 50-60 tons per acre in fourteen months without fertilizer. Over a million acres in the valley are not cultivated and if this were put under sugar-cane, production could compete with that of Cuba. The rainfall is only 45 inches per year but there is abundant subartesian water at shallow depth.

While there had been general insistence the need to return sugar-cane trash to the soil, trash conservation trials at Bundaberg since 1933 have shown no difference in the yield of sugar. Any increase in production obtained overseas is due apparently to the potassium contained in the trash, while in Natal and Jamaica there is probably a slight conservation of moisture as well.

With the increasing efficiency of boilers, the industry is presented with the problem of disposing of surplus bagasse, once all used as fuel. In Jamaica, bagasse is applied to the surface of the soil and then by means of a deep ripper is incorporated into the cracks between the large clods. In Queensland, similar use might be made in the heavy clay soils of the Mackay district, helping to improve their physical structure.

Abstract of Proceedings, 30th August, 1954.

The Ordinary Monthly Meeting of the Society was held in the Physiology Department of the University of Queensland on Monday, 30th August. Thirty members and friends were present. The minutes of the previous meeting were confirmed. Miss E. Marks, Mr. H. N. Paine and Dr. H. Winter were elected to Ordinary Membership, and Miss J. A. McDonald was nominated for Ordinary Membership.

An address entitled ''The Use of Models in Structural Engineering'' was given by Professor J. H. Lavery. The use of models for the solution of structural problems has been developed mainly in the last thirty years. The advantages of models are:—(1) the rapidity with which problems can be solved; (2) the possibility of obtaining solutions where mathematical analysis is impossible; (3) the checking of basic assumptions of design. The dimensions and the material of the model are related in accordance with the principles of similitude. These are deduced from established laws of mechanics or by the methods of dimensional analysis. The choice of the material for the model is important and it is necessary to know the physical properties of model and prototype material. For elastic structures, either a direct or an indirect method is used. The former subjects the structure to loads corresponding in model and prototype in accordance with the principles of similitude.

Models which have been used successfully in the investigation of major structures include those of the suspension bridge proposed for the crossing of the Severn River, tested in a large wind tunnel by the National Physical Laboratory in Great Britain, and the Rainbow Arch

Bridge, tested to examine the effect of the change in shape due to dead loads. Examples of full scale structures, tested with the object of obtaining bases for design methods, are the large scale frame building units of the Steel Structures Research Committee, the prestressed foot bridge at the Festival of Britain, slab and beam highway bridges at the University of Illinois and the steel portal structures tested at Cambridge to investigate collapse methods of design.

The indirect method of model testing makes use of the principles of Maxwell and Muller-Breslau. By this means, influence lines for some action in the structure are obtained from the deflected form of the structure subjected to certain displacements by such apparatus as the Begg's Deformeter and the Moment Deformeter. Measurements of the deflected form are made by microscopes reading to .002 mm.

Much of the apparatus used in the Engineering School of the University of Queensland has been constructed in the department's workshops. The models assist in providing students with a picture of the way in which a structure will deform. Without this, any analysis is worthless.

Abstract of Proceedings, 9th September, 1954.

A Special Meeting of the Society was held on Thursday, 9th September, in the Geology Department of the University of Queensland. This was a conjoint meeting with the Queensland Branch of the Geological Society of Australia.

Professor R. A. Stirton spoke on "The Giant Marsupials of Australia." He described some of the results of expeditions which he and his party had recently made to places in New South Wales, South Australia and Queensland in their search for the fossil remains of marsupials. Although they had not been successful in discovering very early representatives of the marsupials and monotremes, he believed they would still be found in deposits of Lower Tertiary age.

Fossil marsupials had been found by the party at various localities and at different stratigraphic horizons. At Lake Menindee in western New South Wales, extinct marsupials, of possible Early Recent age, were found in sands showing evidence of contemporaneous human occupation. Aboriginal burials were found in overlying units. Skeletons of the giant extinct marsupial, *Diprotodon australis,* were found in deposits of possible Late Pleistocene age at Lake Callabonna, South Australia. It was estimated that there were perhaps one thousand of these skeletons in an area of twenty acres. On the Darling Downs, in south-eastern Queensland, fossils were obtained in Pleistocene deposits at King's Creek and further west at Chinchilla, where the remains are older, possibly Middle Pliocene. The most important finds were made at Lake Palankarinna, north-eastern South Australia, where a fauna of probable Lower Pliocene age included remains of two nototheres, a small kangaroo and a bandicoot, all representing new genera.

Possible phyletic lines in Australian marsupials were discussed, and comparisons were made with those known for some of the placental mammals of North America.

Abstract of Proceedings, 27th September, 1954.

The Ordinary Monthly Meeting of the Society was held in the Physiology Department of the University of Queensland on Monday, 27th September. Sixty-eight members and friends were present. The minutes of the previous Ordinary Meeting and of the Special Meeting were confirmed. Miss J. A. McDonald was elected to Ordinary Membership. The Librarian reported that there had been 164 additions to the library.

Following a motion proposed by Professor H. C. Webster, and discussed by several members, it was finally agreed—(i) that the Society rescind its resolution, namely, that A.N.Z.A.A.S. shall continue to have a similar relationship with the Academy of Science as it has hitherto with the National Research Council; (ii) that the Society support the retention of the Australian National Research Council as a more truly representative national scientific body than the Academy; (iii) that these decisions be conveyed to A.N.Z.A.A.S. and A.N.R.C.

An address entitled "Coral Reefs of the Marshall Islands: a comparison with the Great Barrier Reef" was delivered by Professor J. W. Wells. Coral reefs are of unique significance to biologists and geologists in that they are the only earth features of any magnitude determined by the integrated operation of both organic and inorganic agencies. The atolls of the Marshall Islands are ring-shaped reefs enclosing a lagoon which may be as deep as 200 feet and many miles across. A traverse across an atoll from the windward side shows first the reef margin, with an algal ridge several feet above the rest of the reef and low tide level, fissured by surge channels extending down the seaward slope into a zone of rich coral growth reaching from about wave base down to at least 40 feet. Very few corals grow on the algal ridge, but red calcareous algae of the Lithothamnion type thrive in this turbulent environment. Such algal ridges are not developed on the Great Barrier Reef, apparently because of the inconsistency of the south-east trades, and the margin of the reefs slopes more evenly downward into the sea.

Behind the algal ridge lies the reef flat, carpeted with growing coral. The inner part of many reef flats is the site for the development of islands by the accumulation of debris derived from the growing reef by organic and inorganic processes of degradation, and piled up by storm waves. Beyond the islands is a reef bordering the lagoon, sheltered from the wind, where corals grow luxuriantly. Similar reefs occur on the lee of the Great Barrier platform reefs. On the leeward side of atolls the seaward reefs are protected from the constant winds but not from the steady swells. Here there is no algal ridge, and the environment is very similar to that found on the seaward sides of reefs to windward on Great Barrier reefs, and on the fringing reefs common around the high islands and rocky mainland shores behind the Outer Barrier. The different environments of atoll reefs are paralleled by those of the Queensland coast.

Coral reefs are the result of a near balance of constructive and destructive forces. The constructive forces are mainly organic—the accumulation of the skeletons of corals, calcareous algae, foraminifera and molluscs. Destructive forces are both organic and physical. Organic degradation results from the activity of perforating, boring, and dissolving animals and plants; physical degradation involves the destructive and distributive action of waves especially during typhoons. These opposing forces are constantly at work, but, in general, wherever lime-secreting organisms are growing on reefs, the balance is in favour of construction.

Abstracts of Proceedings, 25th October, 1954.

The Ordinary Monthly Meeting of the Society was held in the Physiology Department of the University of Queensland on Monday, 25th October. Twenty-three members and friends were present. The Minutes of the previous meeting were confirmed. The Librarian reported that there had been 111 additions to the library.

An address entitled "Impressions of Technical Education in the United States of America" was given by Mr. P. C. Brooks. After discussing the variation in tuition costs and standards of achievement in various colleges and universities he described some of the special characteristics of the Massachusetts Institute of Technology. Here there was a common course in the first undergraduate year, and in the second year it was necessary for all students to select a humanities course in addition to their technical subjects. The pattern of class study was different from that seen in an Australian University. There was very little formal lecturing, there were semester examinations and sometimes "open book examinations" were held, since it was believed that this more closely approximated the situation in industry. At M.I.T. there was compulsory health insurance for all students and an infirmary was maintained within the campus. Every student had the right to consult a psychiatrist twice a term. The development of a Graduate School in Chemical Engineering and Technology became necessary because of the impossibility of finishing study in this subject in the four years taken for the primary degree. As many as twenty per cent. of chemical engineers went on to the graduate school, including many who came back from industry.

The power of the alumni of American colleges in determining the pattern of development was very high, and the various alumni associations took a keen interest in all matters, including the organisation of college sport. The relationship between universities and industry was close and vast sums of money were obtained from industrial undertakings as well as governmental sources to maintain research projects in widely differing fields, many of a fundamental character.

Abstract of Proceedings, 29th November, 1954.

The Ordinary Monthly Meeting of the Society was held in the Physiology Department of the University of Queensland on Monday, 29th November. Fifty-five members and friends were present. The minutes of the previous meeting were confirmed. The Librarian reported that there had been 217 additions to the Library. Professor D. A. Herbert delivered a Memorial Address entitled "Heber Albert Longman."

A. H. Tucker, Government Printer, Brisbane.

GUIDE FOR THE PREPARATION OF SYNOPSES

1. PURPOSE.

It is desirable that each paper be accompanied by a synopsis preferably appearing at the beginning. This synopsis is not part of the paper; it is intended to convey briefly the content of the paper, to draw attention to all new information and to the main conclusions. It should be factual.

2. STYLE OF WRITING.

The synopsis should be written concisely and in normal rather than abbreviated English. It is preferable to use the third person. Where possible use standard rather than proprietary terms, and avoid unnecessary contracting.

It should be presumed that the reader has some knowledge of the subject but has not read the paper. The synopsis should therefore be intelligible in itself without reference to the paper, for example it should not cite sections or illustrations by their numerical references in the text.

3. CONTENT.

The title of the paper is usually read as part of the synopsis. The opening sentence should be framed accordingly and repetition of the title avoided. If the title is insufficiently comprehensive the opening should indicate the subjects covered. Usually the beginning of a synopsis should state the objective of the investigation.

It is sometimes valuable to indicate the treatment of the subject by such words as: brief, exhaustive, theoretical, etc.

The synopsis should indicate newly observed facts, conclusions of an experiment or argument and, if possible, the essential parts of any new theory, treatment, apparatus, technique, etc.

It should contain the names of any new compound, mineral, species, etc., and any new numerical data, such as physical constants; if this is not possible it should draw attention to them. It is important to refer to new items and observations, even though some are incidental to the main purpose of the paper; such information may otherwise be hidden though it is often very useful.

When giving experimental results the synopsis should indicate the methods used; for new methods the basic principle, range of operation and degree of accuracy should be given.

4. DETAIL OF LAYOUT.

It is impossible to recommend a standard length for a synopsis. It should, however, be concise and should not normally exceed 100 words.

If it is necessary to refer to earlier work in the summary, the reference should always be given in the same manner as in the text. Otherwise references should be left out.

When a synopsis is completed, the author is urged to revise it carefully, removing redundant words, clarifying obscurities and rectifying errors in copying from the paper. Particular attention should be paid by him to scientific and proper names, numerical data and chemical and mathematical formulae.

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