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TRANSACTIONS

AND

PROCEEDINGS

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Royal Society of Victoria.

VOL. XXI.

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Royal Society of Victoria.

1884.

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Royal Society of Victoria.

ANNIVERSARY ADDRESS

OF

The President,

MR. R. L. J. ELLERY, F.R.S., F.R.A.S., Government Astronomer.

(Delivered to the Members of the Royal Society of Victoria, at their Annual Conversazione, held October 3rd, 1884.)

GENTLEMEN OF THE ROYAL SOCIETY,

I think you must experience a sense of monotony as year after year I inflict you with the inevitable presidential address, which, do what one can to impart a little freshness into it, must, coming always from the same pen, necessarily lack that novelty of stuff and style which alone would make such deliverances tolerable. If it be so, as I fear it is, you have yourselves to blame for electing me your President so continually. While keenly appreciating the great honour you have done me in electing me your President for eighteen consecutive years, I have come to the conclusion it will be better for the Society and for me that I should cease to occupy its chair after the end of the present session. New blood, new ideas, new ways of looking at and dealing with things, I am sure, are most desirable in the interests of the Society, and at our next annual gathering of this kind I intend being a listener to a brilliant address from my successor.

PROGRESS AND PROSPECTS OF THE SOCIETY.

The Society is now approaching the termination of its twenty-sixth year, and it is pleasant to be able to tell you that it is in a prosperous condition and full of vitality. The ordinary income, added by the grant annually voted to us by the Parliament, now places us in a satisfactory position. The Society is not only solvent, but it has a small reserve for current requirements. Our buildings are in good order and repair; we have added to our library accommodation, and had a large number of our valuable books bound, so as to be accessible to our members. The increase of the Society, and more especially the want of more space for our large meetings and gatherings like this, has already given rise to a wish for more accommodation in the shape of a large lecture or assembly room, and I have no doubt the Council will take the matter into serious consideration before our next session. Our last session was a busy one, as will be seen by reference to our twentieth volume, issued in May last, and it is gratifying to note how promptly our secretaries have placed the volume for 1883 before our members.

DECEASED MEMBERS.

I regret I have to record the loss by death during the past year of three members and one associate of the Society—viz., Mr. W. C. Watts, C.E., late city surveyor; the Rev. J. I. Bleasdale, F.G.S., who died in San Francisco on the 2nd August; Mr. W. Detmold, died on 4th August; and Mr. J. F. Bailey, who died in July.

AUSTRALIAN BOTANY.

I have usually availed myself of the occasion of our annual gathering to inform you very briefly of any matters of interest in connection with the past year's history of the several public scientific and technical departments, as well as to say a few words on what appear to me interesting facts in the year's advance in knowledge, and perhaps I cannot do better than follow my old custom. You will remember I referred in my former address to a valuable and extensive work on the eucalypts of Australia, undertaken by our State botanist and fellow-member, Baron von Mueller, and you will be glad to hear that the tenth decade of the *Eucalyptography of Australia* is now in the press, and, with the exception of a few supplements, will complete this most important botanical work. Baron von Mueller has also been closely engaged in research concerning the regional distribution of the 14,000 already known Australian plants preliminary to further extension of his utilitarian inquiries into their structural characteristics, as well as into their industrial and therapeutic uses. He informs me that through the liberality of the Government he is now able to issue a monography of the Myoporinæ, an extensive and important order of Australian shrubs, for which he has eighty plates already prepared; he proposes, also, shortly to prepare a new edition of the *Select Plants for Industrial Culture and Naturalisation,* and that at the instance of the Field Naturalists' Club he hopes soon to issue a *Dichotomous Key* for the naming of Victorian plants—a work which will no doubt be hailed with pleasure by all botanical students among us. While on the subject of botanical science I will call your attention to the great loss it has very recently sustained by the death of the illustrious George Bentham, who had by his great work, *Flora Australiensis* (in the production of which our botanist, Baron von Mueller, lent most valuable and substantial assistance), associated his name more closely with Australia than any other part of the world.

NATURAL HISTORY AND ZOOLOGY.

Our Museum of Natural History, so ably managed by Professor M'Coy, increases in scientific interest and popularity every year, and has received numerous valuable additions since I last referred to it, more especially with respect to the invertebrate groups of the general collections of recent zoology, and to all classes illustrative of the zoology of New Guinea and other islands of the Western Pacific. Of the latter a very valuable series has been contributed by the proprietors of the *Argus* newspaper, obtained by their New Guinea exploring expedition. There have also been important additions to the Borneo collection, presented by the Australian Borneo Company. The collection of old red sandstone fossils has been made more perfect by the acquisition of many of the fishes of that era. The growth of these collections brings nearer every year the time when more room will be required in our Natural History Museum.

TECHNOLOGICAL AND INDUSTRIAL MUSEUM.

The Industrial Museum and School of Technology, under the direction of Mr. J. Cosmo Newbery, continues to improve and widen its utilitarian functions each year. The additions to the collections of the Museum, procured both by donation and purchase, have been fully up to the average of previous years. Special endeavours have been made to illustrate, as fully as possible, by specimens all matters of public interest, and some of these collections will be shown in the hall to-night, and will include the modes of occurrence of gold, the occurrence of silver in Australia, Australian diamonds, with other ornamental stones, clays, and other materials used in the manufacture of the finer varieties of earthenware and porcelain, including a number of specimens of ware made in the Museum laboratories. The classes have been well attended, and it is pleasing to note that young men joining the laboratories find that with the knowledge gained in this institution, they can not only enter manufactories where technical skill is required, but that they can also obtain important public positions. A former pupil assistant now holds a high Government post in an adjoining colony, and his successor, Mr. Frederic Dunn, has recently been appointed public analyst for the city of Melbourne.

KINDRED SOCIETIES.

Of the varied kindred societies, I think I may with confidence state that their progress has been *pari passu* with our own. The medical societies, the Microscopic Society, the Field Naturalists' Club, and the Pharmaceutical Society are all in a vigorous and healthy state. With regard to the latter, it is gratifying to see it has permanently established the much-needed College of Pharmacy in Melbourne, where the art will be taught on a basis commensurate with the requirements of modern chemistry and other sciences; and I am glad to say that only a few days ago the Council of our University agreed to accept the certificates of the College as a proof of the proper training of our medical students in this most indispensable branch of medical knowledge. The College presents a means of gaining a thorough knowledge of the art and science of pharmacy, which hitherto has not existed in the Australian colonies. The Field Naturalists' Club, although the most youthful, is perhaps the most vigorous of the societies. It now numbers nearly two hundred members; forty new members have joined the ranks during the last few months, and, *mirabile dictu,* six are ladies. This is a good sign; for considering the attractions offered in the practical study of the sciences embraced by the club, we may reasonably hope the six lady members will soon become sixty—not in age, but in numbers. The Schools of Mines at Ballarat and Sandhurst are as prosperous and vigorous as ever, and are fulfilling their functions admirably in our two principal rural cities. In view of the vigorous administration of the Ballarat School, the excellent class of work and teaching it has established, and the desire to extend its functions wherever it may be of use to the locality or community at large, we are led to hope it will soon become a most important school, and centre of art, science, and industry.

ASTRONOMICAL PROGRESS IN AUSTRALIA.

A few words on the recent progress of astronomy in this part of the world will perhaps not be without interest to you. With well-equipped public observatories at Sydney, Adelaide, and Melbourne, aided by several private astronomers (prominent among which is Mr. Tebbutt, of Windsor, New South Wales), possessing excellent telescopes and other instruments, we are by no means behindhand in the pursuit of knowledge in this direction. As regards our own Observatory, you will be glad to hear its capacity and usefulness have been materially increased by the erection of a fine transit circle of the most modern construction, made by Troughton and Simms, of London. It has an object glass of 8-in. diameter, and is capable of the highest class meridian work. The work done with the great telescope since its erection in 1869, which consists of a revision of the southern nebulæ observed by Sir John Herschel at the Cape from 1834 to 1838, is now in the press, and will be shortly issued in parts, with lithographs of the nebulæ as they appear at present. At the Sydney Observatory, Mr. Russell is busily engaged with work in connection with the trigonometrical survey of New South Wales, in addition to the ordinary astronomical work. I had an opportunity of inspecting this Observatory very recently, and it afforded me the greatest interest and pleasure to examine the various improvements in astronomical and physical instruments which have been devised by my talented colleague. A noteworthy instance is a new mounting of the Sydney 12-in. refractor, which is the most stable mounting I have ever tried. While the large telescope can be moved with great ease, when once it is pointed on an object and clamped it is almost as rigid as a meridian instrument, even while following the diurnal motion of the object steadily and accurately, by means of one of Mr. Russell's double-pendulum governors. The Adelaide Observatory, which possesses a fine 8-in. equatorial by Cook and Sons, has now been furnished with an excellent

6-in. transit circle by Troughton and Simms, and the director, Mr. Todd, intends to extend his operations into standard meridian work. In Queensland the Government are about to carry out a geodetic survey, and to do this a central observatory will be necessary. Steps have already been taken to establish one on a small scale, and a naval gentleman of considerable astronomical experience (Lieutenant Hoggan) has been appointed to take charge. Two or three years ago Tasmania established a small observatory at Hobart, in charge of Commander Shortt, R.N., chiefly for meteorological observation, which is now regularly carried out all over the island. It is, I believe, intended to gradually add standard astronomical instruments to the equipment, and already a transit instrument has been erected for obtaining local time. There are also several amateur observers in Tasmania, who from time to time give valuable aid, and add their *quota* to our general stock of astronomical knowledge. Among the chief points of interest in the year's history of astronomy is the reappearance of Pons' comet. This comet was first discovered by Pons in 1812. On 1st September last year Mr. Brooks, of Phelps, New York, found a very faint comet in Draco, and when a sufficient number of positions were obtained from which to compute its orbit, it was found to be the comet of 1812 returning to perihelion. It passed its perihelion on 25th January this year, and it became visible for some time to us as a moderately bright object in the western sky. An interesting fact in connection with this comet was the occurrence of certain sudden outbursts of light in the nucleus. Ordinarily a comet increases gradually in brilliancy as it gets nearer the sun; but in this case, between seven p.m. and eleven p.m. on 22nd September, it increased its brightness forty times more than is commonly the case, and then waned. Again, in one hour and three-quarters, on 1st January, an outburst of light took place which soon declined pretty rapidly to its original brightness. The comet was not seen here till the 6th January. While looking rather far afield for Pons' comet in January last, Mr. David Ross, of Elsternwick, discovered on the 12th an object which he thought was this body, and reported it to the Observatory, where it was soon found to be another, but very small comet, which we called Ross' comet. Its apparition was of short duration, and it was never visible in the northern hemisphere. On 25th September next year there will be a total eclipse of the sun, the central line of which passes over New Zealand just about Cook's Straits, and this is the only land on which it will be visible as a total eclipse. The duration of totality will, however, be small—about two minutes and a half only. It nevertheless affords for a few precious moments a view of the circum-solar regions divested of its usual dazzling light, which will be of inestimable value to astronomers, and which they are content to travel half around the world to secure, for adding further to our knowledge of the solar surface and surroundings, and to search for any planetary bodies that may exist within the orbit of Mercury. It is not unlikely our Observatory will send a small observing party to Wellington, or to the neighbourhood of Cook's Straits, to undertake some part of the requisite physical observations; and although I have yet heard of no European or American party being organised for observing the phenomenon, there is little doubt that several astronomers will visit New Zealand on this occasion.

EARTHQUAKES AND EARTH TREMORS IN TASMANIA.

The remarkable prevalence of earthquakes and earth tremors in Tasmania, Bass's Straits, and the south-eastern portion of Australia during the last twelve or fifteen months affords a subject of considerable scientific interest. Fortunately, none of the disturbances, so far, have been of sufficient intensity to do much damage, although a few, and notably one of 13th July, were sufficiently severe to cause considerable alarm. The tremors and shakes have been experienced chiefly in the north-east districts, but to some extent generally over Tasmania, since July, 1883. It was not until February, 1884, that they were noticed on this side of the Straits, when a severe shake was felt by the lighthouse people on Gabo Island. Since that date, however, no less than twelve shocks of small or moderate intensity have been reported from this and other places in Gippsland, the last occurring on the evening of the 19th of this month, when the tremor was sufficiently intense to cause the lighthouse at Gabo to tremble, and things on the table to dance about. This shake was also felt at Port Albert, Wilson's Promontory (where it "shook windows and furniture violently"), Cape Schanck, Omeo, and other localities in Gippsland. The vibration lasted over a minute and a half, and appeared to have a direction from south to north. There are one or two remarkable facts noticed in Tasmania in connection with these seismic disturbances. The first is the tremulous character of most of them, producing a sensation of a distinct tremor of the earth's surface, frequently continuous for a considerable period—in some cases for hours, and very frequently for over an hour. Many observers state as their experience that the tremors appeared to be on the surface, and not extending to deeper strata. This is somewhat supported by reports I have received from Mr. Grant, mining manager at Branxholme, on the Ringarooma River, North-east Tasmania, who has kindly furnished me with his observations of over one hundred earthquakes and tremors which have been experienced in his locality since January of this year. This gentleman called my attention a year ago to the fact that most of the tremors and rumblings, while startlingly manifest on the surface, were not noticed 12 feet or more below it, except sometimes in the open timbered shaft of the mines. Even in deep cuttings they were often unnoticeable. Another remarkable point is that in some of the stronger tremors, while ferns and low bushes were seen to tremble and wave about rapidly, no movement whatever was noticed in taller trees. When it is low water in the Tamar at Launceston a long range of mud-flats are seen from the town, extending some distance down the river, and on one occasion during a strong tremor the surface of these flats was seen to be agitated as by a series of very short waves passing over it. I extract the following from notes furnished me by Mr. Grant:—"25th July.—Barometer, 30·05. Fine and clear. 4.40 a.m. a shock, and 10.34 a.m. a moderate shock. This shock caused a peculiar vibration of small ferns and under-scrub. They commenced to tremble quickly at first, but increased in intensity till the maximum of the shock, when the vibration died away as the wave passed over. It did not appear to affect the large trees or moderate-sized saplings, only the herbage close to the ground. This was the first time I observed the phenomena. Again, on 11th August, at 2.41 p.m., during a slight shock, preceded by a loud rumbling, no vibration of the ground was felt, but the smaller or ground herbage was seen to tremble, the motion proceeding from north-east to south-west; the loftier scrub and trees showed no motion." Another gentleman, who is strongly of opinion these disturbances are superficial, and not subterranean, states that he has spent much of his time below ground during the last twelve months at Mount Victoria (North-east Tasmania), but during all the tremors and earthquakes he never felt the slightest indication of a tremor under the surface. He has heard the rumbling noise near the surface in the shaft, but felt no vibration. He says that his companions on the surface have frequently hailed him to tell him an earthquake was passing, but failed on every occasion to discover any vibration or tremor underground, though sufficiently near the surface to hear the rumbling noises. Commander Shortt, of Hobart, informs me that the ship "Helena" felt the shock of 13th July, 150 miles to the eastward of Cape Barren Island, and that the water around her appeared convulsed. The collected observations of 13th July, and of the severer shakes since, make it pretty certain the direction of the seismic waves has been always from north-north-east to south-west in Tasmania, and from south to north on the Australian coast. This seems as if the waves radiated from a centre either in or about Banks' Straits, or from some point at sea to the eastward of these places, and very probably about the locality the "Helena" felt the shock. I regret I have got no intelligence from the islands yet concerning the disturbances; for any precise observation from there would greatly help in giving a *locus* for the seismic centre. The evidence available, however, strongly supports the foregoing assumption. While there is ample evidence of extensive old volcanic action in the Australian group, we have always regarded these regions (of course including Tasmania) as far removed from any centres or line of seismic activity, and during my thirty-three or thirty-four years' experience in this country earthquake shocks have been of considerable rarity, and always of very small intensity. These repeated and continued tremblings, therefore, constitute a new order of things, and a problem for the geologist and physicist; but let us hope they will not become sufficiently severe to present a problem also to the architect, as they do in Japan.

THE RED SUNSETS.

We have not yet done with the red sunsets and afterglows, although they always appear now with much less intensity than formerly. The true cause of them appears to be still an open question, but I think we may assume that the "Krakatoa eruption theory" is not such a favourite as it was six or eight months ago. It has been found out that red sunsets and brilliant afterglows were not uncommon before the Krakatoa outburst, as we in Australia well know, and I dare say it will be eventually discovered that the great catastrophe of Sunda Strait directed special attention to peculiar atmospheric appearances, which after all were not of any particular rarity.

RAINFALL AND WATER CONSERVATION.

The late disastrous droughts in the central districts of Australia direct our attention to the questions of rainfall and conservation of water. If we gather together the statistics of rainfall for Australia for all the years in which records have been made, and plot them graphically, as I have done in the rainfall maps for the last two years, a very prominent fact appears—namely, it is only a fringe around the great continent, deep in some places, narrow in others, and much serrated in portions—that is blessed with sufficient rainfall to render successful agriculture possible, while over a vast central area the average is so small as to make it a matter of surprise that in such an arid region can be maintained vast flocks of sheep, which return in favourable seasons enormous wealth in the shape of wool. Now, over the regions I am speaking of the average fall is from 10 in. to 5 in. per annum. This seems to be the maximum that can be expected in the most favourable years, and it is now well known that favourable years are the fewest. It appears inevitable, therefore, that to avoid disaster and loss flock-owners should not be tempted by a year or two, when the rainfall has not only been near the maximum, but also well timed, to increase their flocks beyond their power of maintenance in the drier years which are always found to follow. If we examine the rainfall map we find that between these comparatively arid central regions and the coastal fringe of bountiful rainfall lies an area, in some measure parallel to the coast line, but whose inland margin is very irregular (owing to the physical features of the country), which is shaded to represent an annual fall of from 15 in. to 20 in. This margin may be assumed to be the limit of our wheat-growing areas.

M. PASTEUR'S DISCOVERIES.

It has long been known that certain diseases to which man is subject rarely attack the same individual twice, and this is especially the case with small-pox, typhoid fever, and less markedly with measles, scarlet fever, &c. We are also familiar with the fact that inoculation with small-pox poison used to be resorted to with the view of inducing the disease in a mild form, and so purchasing future immunity from the more severe and dreaded forms of the disease. Inoculation with small-pox virus gave way to vaccination, which has now for many years constituted the one great preventive of the spread of small-pox, and the safeguard of the individual against proneness to the disease, and especially to its most virulent forms. The principle of inoculation for inducing mild types of other diseases has been advocated, and, indeed, practised, with more or less success, as was the case with pleuro-pneumonia and anthrax in cattle. Pasteur some time since made a number of experiments on animals, and appears to have proved that some infectious diseases, destructive to fowls, especially chicken-cholera, induced by inoculation, protected the individual from future attacks of the same disease. More recently he carried out a series of analagous experiments with regard to rabies or hydrophobia in dogs. The results he announced are not only interesting, but, if borne out by future experience, of the utmost importance; not merely as relating to hydrophobia, but in connection with the general question of inoculation with disease poison. The results of Pasteur's investigations, as given by himself, are that dogs inoculated with rabies poison get the disease in a fatal form; that if a monkey is inoculated with the virus from a mad dog it contracts the disease, but in a milder form; if a second monkey is inoculated with the poison from the first it takes the disease still more mildly, till after the third removal from the dog through monkeys the virus becomes so far attenuated as to induce hydrophobia in a very mild and non-fatal form, and dogs so inoculated remain protected against the further virulent poison of a bite from a rabid dog. M. Pasteur states he found that if instead of monkeys he used rabbits or guinea pigs for successive inoculations, the virus appeared to be so intensified, rather than diluted, that dogs inoculated at the third removal took the disease with greater virulence than if the poison used had been taken from an ordinary rabid dog. Should these results be confirmed it opens up a most important field of research to the pathologist and physician, and makes reasonable the hope that we may some day have the prophylactic principle, so successful as regards vaccination against small-pox, applicable to other serious contagious and epidemic diseases.

DISEASE GERMS.

During the last few years the question of disease germs has occupied the attention of numerous well-known biologists, microscopists, and others, and we have seen announced from time to time the discovery that certain forms of microscopic organisms appeared in connection with certain diseases, and are regarded rather as a cause than an effect. In nearly every instance these organisms were found to be of forms known as bacteria, bacilli, and micrococci, which, in one or other of their varieties, are said to be of all disease the accursed germs. It is stated that in anthrax or splenic fever, and in a peculiar malady known as woolsorters' disease, a special form of bacterium is the delinquent; while in diphtheria, cow-pock, and in a disease amongst fowls known as chicken-cholera, micrococci are the cause; and in tuberculosis and leprosy the bacilli are concerned. Recently during the cholera outbreak in Europe it was announced that Professor Koch had discovered a peculiar comma-shaped bacillus in the alimentary canal of persons affected with the disease, leading to the inference that these germs were the cause of cholera. If this be true, it leads the way to give successful battle to the disease. But although the presence of these germs in various forms of disease has been demonstrated beyond a doubt, the relation they hold to the diseases themselves has not yet been so satisfactorily proved. Those minute organisms in some of their forms are universally present wherever organic change or decay is going on—and especially where vitality is impaired—present in the saliva, in the fur of the tongue, and about the teeth in healthy persons; indeed, it may be doubted if they are not always present on every mucous surface exposed to air and chemical change. It is difficult, therefore, to admit, in our present state of knowledge, that they are necessarily the cause, or even the carrier, of the disease which they are always found to accompany. On the other hand, having regard to the part played by the yeast plant in producing fermentation, and to the induction of disease by inoculation, it appears quite possible that these minute organisms might be carriers, if not germs, of disease. While, therefore, withholding judgment, we cannot fail to watch with the greatest interest and admiration the untiring investigation of Professor Kohn, Professor Koch, Dreschfeld, Pasteur, and others. In this particular line of research some of our own members have already essayed inquiry, and have contributed the results in our last year's Transactions. It is an ample field, every advance in which confers a boon on humanity; and, in concluding, allow me to express the hope that next year we may find that our Society has contributed substantially to this most important subject—for questions bearing upon prevention and arrest of disease, on sanitation, and upon many cognate questions in social science, are among the most useful and important our Society can occupy itself with.

TRANSACTIONS.

Art. I.—*On the Evidences of a Glacial Epoch in Victoria During Post-Miocene Times.*

By G. S. Griffiths.

[Read 13th March, 1884.]

Having had occasion to pay frequent visits to our goldfields, the boulder washes which accompany many of our alluviums, especially the richer ones, have always excited my wonder and curiosity. The heavy boulders of which they are composed are embedded in a matrix of silicious cement, or of hard clay, and the formation is found in strips and sheets, flooring our leads and valleys, capping our hills, and terracing our mountains; and they sometimes stream across country, traversing the gullies and ranges, regardless of the levels or of the drainage lines.

These conglomerates are generally believed to be the remnants of ancient and deserted river beds. We are told that the streams which deposited them have since shrunk into trickling rivulets, and that, meanwhile, their courses have shifted from time to time, until, at last, they for ever left their old beds, although we now know, on the best authority, that the river system of a country is even more ancient, more permanent, more indelible, than its mountain system ("Rivers and River Gorges," A. Geikie, in *Eng. Ill. Mag.*, Jan., 1884). That as they shifted about they left behind them, as well as above, these ancient, stone-paved beds, winding about aimlessly and crossing older tracks, until the geological map which records them is covered with a network of lines. We are told, also, that the denudation which this country has undergone is very great in amount, and that it has entirely changed the aspect of hill and vale, so much so that we find, here and there, old river beds running along the backs of spurs, as is the case at Cobungra.

This explanation, although it contains many truths, does not seem, to me, to be entirely satisfactory; and the more carefully I examine the boulder washes the less do I feel disposed to acquiesce in it.

The facts which are not explained by the fluvial theory may be briefly stated.

In the first place, the observer is struck by the frequency with which washes containing huge boulders occur close to the sources of small rivulets. These insignificant gutters of intermittent flow are quite inadequate in power to carve out this drift. A stream of water with some volume is required for the purpose. To get a stream a watershed is necessary, but the gathering ground of some of the gullies which contain these boulders in abundance is insignificant. Thus, the water-power required is not only wanting, but, to all appearance, always has been. This is not merely my own individual opinion, but it is one which has been expressed strongly by many geologists.

On a col. between Mounts Lookout and Taylor, in Gippsland, Mr. A. W. Howitt reports a wash of boulders and rolled gravel (Smyth's *Goldfields*, p. 123). On this saddle there is no stream, and no watershed to feed one; even the surface runnels cannot unite until they reach the lower ground, where the hill flanks gather themselves up into folds and troughs. Nor can it be shown that where the saddle now stands a watershed ever has served it, and has since been removed by erosion. The only effect of erosion is that the saddle has been lowered. In what manner, then, has flowing water cut out and laid down this boulder bed?

We find similar deposits placed high up the flanks of the Warrenheip Range, 1750 feet above the sea level. The boulders are of immense size, and the wash has been traced along the valley for miles. It once filled up the whole depression, but now only remnants fringe the sides (Murray's *Rep. Ballarat Geo. Survey, Vict.*, p. 66).

At Creswick, on two hills, there is a deposit which varies in thickness between 4 and 60 feet. It occurs at an elevation of 1400 feet, and consists of brown clay, quartz, gravel, pebbles, and boulders. Some of the latter are as much as four feet in diameter, and weigh over a ton. The age of this deposit is lower pliocene (Lock's *Gold*, p. 931).

Krausé describes a drift near Ararat, at 1100 feet above the sea level, which is a mixture of clay, gravel, and angular boulders, and which is occasionally 100 feet thick. In his report he points out that these large boulders are found at the very sources of the leads, where little or no fluvial action can have taken place (*Gold*, p. 650).

Without multiplying such instances any further, I will quote to you an opinion expressed many years ago by Selwyn, who wrote as follows:—"The wide spread of the formation over hill, plain, and valley, its uniform character, and the peculiar rounded and water-worn nature of much of the material composing it, are features that appear to require for their production some cause having a much more extended, uniform, and powerful action than can well be ascribed to river floods" (Selwyn's *Notes on Vict.*, p. 25). Similar opinions have been expressed by Murray (*Geo. Sur. Rep.*, p. 68), Krausé (*Gold*, p. 650), Brough Smyth (*Goldfields*, p. 154), Howitt, and others.

When we reflect upon the transport power of running water, as it is exemplified around us, we must feel still more dubious of the fluvial origin of these drifts. If we turn to the well-observed rivers of Great Britain, we find that three miles an hour is the maximum speed of the Thames, the Clyde, and the Tay, and that one and a half miles per hour is a moderately swift current (*Stevenson on Reclamation*, p. 18). Further, we see that a velocity of one and a third miles per hour will transport pebbles one inch in diameter, and one of two miles per hour pushes along the bottom slippery stones of the size of an egg. Now, as three miles is the maximum speed of any British river, and as a two-mile current cannot propel stones larger than an egg, no British river could transport such boulders as encumber our drifts. And as there are no Victorian rivers which exceed the swiftest British rivers—the Tay, for instance—in the strength and speed of their currents, these boulders must, in an equal degree, be beyond their powers also. But if we suppose that the Victorian rivers were, in late tertiary times, much larger and swifter, so as to equal the swiftest known streams, would they even then be able to create these conglomerates? I think not; for whatever speed our rivers may have had down to the foot-hills, they could not have run swiftly across the flat plains, and these deposits are found far out upon them, as far away as the Murray banks at the Campaspe, and even out on the Darling. These vast plains have at the outside a slope of two feet in the mile, and the Murray, between Albury and Echuca, falls less than one foot (B. Smyth's *Goldfields*, p. 206). What evidence have we that such a small incline could endow a river with the power to transport, however slowly, these heavy conglomerates for long distances across wide plains? Absolutely none that I can discover.

If we turn to mountain torrents as an efficient cause, we find that they may have for short distances, and during brief periods, a speed of from 18 to 20 miles per hour (Geikie's

Text Book, p. 363), and that they are the most powerful fluvial agents known. But they lose their power when they leave the mountain side, so that their agency will not avail us to explain the occurrence of boulder deposits out on the distant plain, or far down gentle valleys.

Nevertheless, as many of our conglomerates occur amongst the hills, we will see what may be the precise nature of torrential action.

On the coast of the Mediterranean, between Toulon and Genoa, the Alps rise almost sheer from the beach, and a number of streams descend through steep mountain gorges and plunge into the sea. For eight months in the year their beds are dry, and during four months the snow waters come down in tumultuous torrents, spreading out fanwise directly they reach the mountain foot. No water-power of greater force per volume than these streams show is known; and yet, with all their force they are unable to keep open their own channels. As the flood widens out on the short, flat coast-strip, it weakens and drops its load. All that enters the ocean is sand and mud, with some lime in solution. A mass of shingle lines the strand.

Every year, after the snow waters have ceased to flow, the Governments of France and Italy have to spend much money to clear the coast road of the bouldery rubbish which these torrents leave behind them. The same phenomena are repeated wherever mountain streams reach the level lands below, for the boulders come to rest directly the torrential character is lost (Lyell's *Prin.*, Vol. I., p. 491). Therefore, if our conglomerates were the product of torrents, they would occur in fan-shaped deposits of limited extent, which is certainly not the case; for, on the contrary, our boulders straggle all over the country in irregular streaks, sometimes fifty miles long.

If we can suppose the above objections to the fluvial origin of the boulders to be explained away satisfactorily, there yet remains another difficulty in the way of its acceptance. This lies in the fact that the violent nature of this mode of transport is such that the boulders would be ground down into gravel, sand, and mud long before they could reach the distant points at which we find them. Professor Geikie states that granite blocks lose 40 per cent. of their bulk by the time they have travelled the first fifteen miles, although the rate of wear is less afterwards (Geikie's *Text Book,* p. 372). Therefore, if we could suppose the motive power to be available, still the boulders would be reduced to pebbles while they were in the act of being conveyed between the ranges and the Murray. And yet great boulders, which must have travelled long distances, abound in the Murray bed, at the Campaspe junction, and elsewhere (Hodgkinson "On the Geology of the Inter-Mitta-Mitta and Campaspe," *R. S. T.*, Vol. I.).

Surely their wide distribution requires some other agency than that of flowing water. If, knowing as we do that the sea covered these plains not long since, we seek it in the ocean, we still fail to find any evidence that its waters could have formed these deposits. The transport power of the ocean is very limited. Where very strong currents prevail strips of boulders occasionally line the strand, but they never move seawards, and only during storms do they travel along the coast at all. If a sea margin is encroaching on the land these deposits are in time left out at sea, and in this manner they may acquire a travelled appearance. But they lose their size, as they pass through the surf, by getting ground down. When Darwin found Patagonia buried under a superficial stratum of such materials, he at first imagined that the boulders might be products of the ocean, and he tested the neighbouring seas to ascertain if they were similarly boulder-strewn. Careful soundings showed him that the boulders were always ground into pebbles before they left the surf. At a distance from the shore of three miles they were never larger than a walnut; at seven miles there were none larger than a filbert, and at twenty-two miles out they had been reduced to a coarse sand, the grains of which were not larger than one-tenth of an inch in diameter. And he found that throughout this width of littoral the diminution in size of the stones was gradual (*Geological Notes on South America,* p. 16). We may therefore dismiss the ocean from our minds, as far as this deposit is concerned.

Upon a review of all the circumstances, it appears to me that the sculpture and distribution of boulders is not, in the main, due to water-power, and I am acquainted with only one agency which is capable of doing the work, and that is ice.

The power of ice is unquestionable. Frost breaks up rock surfaces rapidly, and wedges off masses. The surface ice of frozen streams destroys the river sides. Ground ice, or anchor ice, as it is sometimes called, envelopes the boulders and gravel of the stream bed, lifting them up, and floating them along with the current. In this manner streams may rapidly transport material that the current, unaided, could never stir. Glaciers carve into the mountains, and scoop valleys and lakes out of stony plains. They level hills, and fill up valleys with the spoil. They carry *débris* as far as they go, and then drop it in huge mounds; or, if they are situated on a water edge, they transfer it to bergs and floes, which distribute it still more widely. As a transporting agency, ice is the most powerful known. In the present age its potency is restricted by the moderate climatic conditions prevailing. But there have been periods when very different conditions held sway, and this agent was then free to operate upon a grander scale, and over vast regions of the earth now outside its influences. The zones, now temperate, show land surfaces teeming with the evidence of its vast mechanical powers.

If Victoria has ever had a climate which would supply the ice required for boulder transport, we ought to find some evidence of the fact besides simple boulder washes.

The characteristic signs of intense ice action consist in rock striæ, or scratches, more or less parallel; in glacial lake basins, in rounded rock surfaces, and hills of flowing outline; in the *débris*, the litter, the refuse of their work, strewed sometimes in heaps, and at other times spread out in sheets of clay, sand, and rock fragments. Lastly, we have the loëss, or loamy secondary product—the sifted-out grindings of the icemill, washed out of the coarser stuff by the snow waters, and swept down the slopes in muddy torrents to be dropped quietly in the still reaches of the flooded plains, and in the shallow sea margins, as a mantle of fertile alluvium.

Let us now see whether any such traces of glacial action—which can be assigned to post-miocene times—have been discovered in Victoria.

I will preface the evidence I shall produce by admitting that the indications, if viewed separately, are ambiguous; but if they are regarded all together they show such a converging trend upon the part of a large number of small facts that they carry conviction; for they all, to my mind, point toward a period of great climatic extremes not far remote in a geological sense.

Taking rock markings first, their occurrence here has been questioned by many. I do not claim to have seen any myself, but Mr. Wm. Lee, a practical miner of experience, assures me that he has seen ice striations near Wilson's

Promontory. The Rev. W. B. Clark reports ice markings on the mountains of New South Wales, and the Rev. Julian Woods, in his *Geological Observations in South Australia,* writes (p. 20) that "it seemed to him that there were very distinct marks of snow and action of glaciers" on the flanks of Mount Lofty, near Adelaide. Mr. Gavin Scoullar read a paper some time since before the Adelaide Philosophical Society, in which he describes a boulder drift at Hullett's Cave which rests upon a well-striated pavement of rock (*P. S. T.*, 1877-79, p. 65).

Professor Tait, in an address to the same society, describes smooth, striated, grooved rocks in the bed of the Inman, Cape Jarvis (*id.*, Vol. LXV.). Selwyn had seen these last-named rocks long before, and he tells us that "the direction of the grooves and scratches is east and west, in parallel lines," and he adds—"I do not think they could have been produced by the action of water. They strongly reminded me of the similar markings I had so frequently seen in the mountains of North Wales" (Selwyn's *Notes on South Australia*, p. 4).

Professor Tait also describes smoothed, grooved, striated rock surfaces, and morainic *débris* of angular blocks of red granite, gneiss, hornblende, and quartz, at Black Point, Holdfast Bay; and he points out the circumstance that the nearest source from which these rocks could have been obtained is thirty-five miles distant. All these South Australian indications of ice are said to be of pliocene age (*id.*, Vol. LXIV.).

I am not aware of the occurrence of any other examples of rock striæ, within South-eastern Australia, of post-tertiary date. There are others to be found, as those of the Lederderg, but they are believed to be of miocene age.

The scarcity of such evidence is accounted for easily in several ways. For instance, rocks differ in their capacity to retain markings. Limestone, serpentine, and clay ironstones polish well, and preserve their striæ long, while sandstones streak faintly and weather quickly. All the softer rocks, and those which are highly jointed, break up rather than polish (*Great Ice Age,* pp. 16-21). Further, those which are impregnated with salts decay quickly. Now, our silurian slates, sandstones, and shales are loaded with iron oxides, and are upedged; while our recent marine sandstones abound in the chlorides of magnesia and soda. Therefore our rocks are to a large extent ill-suited either to receive or to retain ice scratches. Most persons must have been struck by the rapidity with which the finer chisel marks upon the stone faces of our public buildings and the lettering of our monuments and tombstones have lost their sharpness of outline, for, short as is the time during which they have been exposed to the weather, they have begun to decay. But even the hardest rocks will lose their markings if they are not covered in some way; and in a newly-settled country any marks so overspread as to be preserved might long lie concealed. Again, thin ice does not leave behind it striæ, moraines, or till. Such are the products of massive ice alone, and to nourish such high land is required. Now, Victoria has not a large area of mountain land; the scope of such ice action would be restricted to its neighbourhood, and there would be but little use in searching for its traces over the lower and larger area. Frigid as is Siberia's climate, its flatness is such that she cannot show any of the deeper traces of glaciation, and yet snow and ice cover the country during large portions of the year (*Great Ice Age,* p. 555). Near the Rocky Mountains of North America there is a large patch of country quite bare of such traces, while all around it they abound (Geikie's *Text Book,* p. 899). This absence is due to some local peculiarity, and not to the non-occurrence of a glacial climate, and therefore the absence of such evidences is not conclusive as against the occurrence of a glacial climate. Bearing all the circumstances to which we have adverted in mind, we ought not to wonder at rock striæ being scarce, but rather we might feel surprised that any should have been preserved.

We have, in the next place, to look for any ice-scooped lake basins, which are only striæ on a larger and deeper scale. These, also, are infrequent here.

Lake Omeo seems to be fairly identifiable as one. It occurs on a rocky plateau 3000 feet above the sea level, and is three and a half miles long by one and a half broad. It has no outlet, and appears to have been hollowed out of the rock. I understand that Mr. A. W. Howitt attributes several other lakelets in this district to ice action.

Several of the Tasmanian lakes are of glacial origin, having been ice-dug out of solid stone. Such an one is the Great Lake, twelve miles long, and Lake St. Clair, ten miles long (Wallace's *Australia,* p. 242).

When considering the existence amongst our hills of glacial lakes, we must remember that glaciers fill up, as well as scoop out, these rock basins, and that they often leave finally a plain of deep alluvium to replace a rocky floor removed. Lake basins thus obliterated are hard to identify, and may be overlooked easily. Some such levelled-up mountain tarns are known to exist here. Mr. J. Stirling has recently described one in a paper contributed to this Society entitled the "Physical Features of the Australian Alps." In it he writes thus:—"Occupying the valley of the Livingstone Creek since the lower silurian rocks became metamorphosed into the present crystalline schists were a series of ancient lakes or tarns, into which, by the breaking up of the ancient lava flows, masses of igneous boulders became deposited. Subsequently the gradual wearing down of the metamorphic schists, with their associated auriferous quartz veins, filled up these ancient lake beds with a deposit of boulders and auriferous gravels. Ultimately the Livingstone Creek . . . eroded a channel along its margin, leaving the deposited gravels, with their underlying false bottom of igneous boulders, literally high and dry above the bed of the latter stream" (*R. S. T.*, 1882, p. 106). Now, there can be but little doubt that it was the glacier which scooped out this lakelet, and also broke up the *débris* with which it is filled. As the ice melted a watery flood swept down the glacier rubbish from above, and levelled it to the brim. Then the surplus *débris* passed on to fill up other pools lower down. The mountain creek which succeeded to the glacier eventually cut through the formation and revealed the story.

Brough Smyth records that there are amongst the Gippsland hills many level tracts of alluvium, from 200 to 300 acres in extent, surrounded by precipitous rocks and situated at the junction of streams. I think that these will eventually prove to be similar filled-up tarns of glacial origin (B. Smyth's *Goldfields*, p. 12).

In the watershed of the Ovens there are hollows in the granite, now filled up with sedimentary strata, which may also be numbered amongst the traces of ice erosion in Victoria (B. Smyth's *Goldfields*, p. 83).

If we step down from the mountains we shall see that our miners have discovered, beneath the smooth wide plains and the softly swelling rises which diversify them, an ancient land surface of very different contour. This concealed earth-surface is composed of bare silurian rock, which has been sculptured by natural agents until it is ribbed and guttered like the fluted face of an old clay cutting, but with this great difference, that cuttings are generally steep enough to create the waterflow required to carve them, whereas the plains we have in view are inclined at very low angles, and therefore are traversed only by sluggish streams. The corrugations of this rocky surface are masked by an accumulation of clay, sand, gravel, and boulders, and in part by intercalated lava flows. These gutters trend from the Dividing Ranges at a broad angle, those to the north dipping under the Murray at a depth of from 300 to 400 feet from the present surface, and those to the south disappearing beneath the recent alluviums which swathe the foot-hills (*G. S. V.*, Vol. VII., pp. 80, 81). These gutters are the "leads" of the miner; and our present interest in them lies in discovering the means which eroded them. Our choice of agencies lies between water and ice, and if we incline towards the latter it is because we see that these leads traverse country which has but a slight fall, and because we see that they have been filled up by the "spoil" characteristic of ice action. I believe that it was the ice plough first, and flowing ice-water last, which furrowed them and then filled them up.

The next product of glaciation which I shall point out to you is the smooth-swelling rock surface which tells of massive ice moving slowly across the country and planing down all prominences into flowing outlines. Such contours we have on a large scale—undulating, rounded hills,—a constant feature of all Victorian landscapes; but of the minor form —the *roche moutonnée*—we have no example that I can hear of in Victoria. We have to visit South Australia to secure the missing link. Professor Tait has described the occurrence of dome-shaped rocks at Kaizerstühl and Crafers, two localities in that colony (*P. S. T.*, Vol. LXIV.).

We therefore come to the last feature of glaciation—to the rubbish which has been planed and ground off; to the clays, the sand-drifts, the gravel beds; to the cemented conglomerates and the loose boulders.

All these we have in abundance, filling up the hollows, crowning the rises, terracing the mountains, and sometimes, capped with basalt, standing out on the open plains all alone, solitary outliers, the remnants and measure of eroded plateaux.

Before we describe the alluviums in detail it will be a guide to us, in discussing their origin, if we remember the characteristics of well-attested ice *débris* in Europe and America.

Jas. Geikie in his work, *The Great Ice Age,* speaks of them as consisting of sheets of "sand, gravel, and widespread deposits of clay" (p. 4); also, as "a stiff sandy and stony clay, varying in colour and composition, according to the character of the rocks of the district in which it lies. It is full of water-worn stones of all sizes, up to blocks weighing several tons" (A. Geikie's *Text Book,* p. 161).

Let us compare these descriptions with the following:—

Mr. R. H. Stone, mining surveyor, writes as follows of certain deposits in the Ovens:—"The bed-rock is very uneven, consisting principally of soft yellow sandstone with veins of slate intermixed, and occasional bands of hard blue stone (metamorphosed slate). . . . The auriferous drift consists of heavy water-worn gravel and sandstone boulders, slightly intermixed with quartz, and having here and there layers of ironstone cement. In some places there are enormous boulders of bluestone rock, sometimes weighing many tons. The drift is from 3 to 50 feet in depth, and is covered with red loam. . . . Some portions of the drift are very hard and difficult to work, and others so loose as scarcely to require the use of the pick" (B. Smyth's *Goldfields,* p. 84).

The following example occurs in the Buninyong Estate Claim, near Ballarat, which is thus described:—"From No. 8 shaft the drive at 410 feet suddenly entered a mixed mass of clay, angular fragments of silurian, from a small size up to several feet in diameter, angular quartz, and dense blocks of exceedingly dense lava, piled one on another, or isolated through the mass. . . . A few isolated nests of gravel were encountered" (Lock's *Gold,* p. 673).

Mr. O'Farrell, chairman of the Maryborough Mining Board, reports that on a hill two and a half miles from that town the depth of sinking was from 16 to 24 feet, "through hard cement mixed with large white boulders;" and also "that at Majorca the sinking was 85 feet, through stiff clay, gravel, and cement. The washdirt was white gravel intermixed with white boulders" (B. Smyth's *Goldfields,* pp. 97, 98). Similar examples are so numerous that the only difficulty has been to decide which to select.

To show how widely this deposit is distributed, I will give three other instances. On the Wimmera, near the edge of the mallee country, the wells pass through marly clay, sand, shells, gravel, and boulders, and then bottom on a rotten granite. At Kiandra, in New South Wales, the sinking shows the following strata:—Surface soil with floating boulders of basalt and large blocks of cement, 7 feet; clay, 20 feet; lignite, 18 feet; sand, 3 feet; fine drift, 65 feet; coarse drift, with big boulders of quartz, jasper, and ironstone, and containing gold, 6 feet—total depth, 119 feet (*Gold*, p. 510).

At the Field River, in South Australia, there is a deposit of clay and rough blocks of stone piled up indiscriminately (*T. P. S.*, Vol. LXIV.).

At Gnomery, beyond the Darling, and Fort Burke a well has recently been sunk 192 feet, through sand, clay, and silt. At the depth mentioned a layer of granite boulders and pebbles was encountered.

These deposits answer closely to the typical till of the Old World; but if we examine the great bulk of our alluviums we shall notice in them only a general resemblance. We discover similar materials, but they are more assorted and stratified. Our deposits are those of till which has been rearranged. Massive ice first turned the glacial drift out of its grinding mill; then melting mountain ice, in torrents, tumbling from level to level, stripped the till from hill flank and valley side, swept it into the still reaches of the flooded lowlands, and thence carried it out into the shallow sea which occupied all the plains. In these quiet waters the materials were roughly assorted and spread out. In this operation the pre-existing features of the country were completely obliterated by the *débris* shot upon them.

Geologists have described similar operations in other countries. James Geikie, in his work, *The Great Ice Age*, remarks that "the disappearance of a *mer de glâce* was doubtless accompanied by excessive floods;" and further, that "we might expect to meet with evidences of such floods in the presence of more or less tumultuous accumulations of gravel, shingle, and boulders. . . . This drift sweeps up and over considerable hills, and occurs on the tops of plateaux and on the dividing ridges of separate river basins. . . . That the drift is not now more continuous is due to subsequent erosion" (pp. 264, 265).

As an illustration of the water-power set free during the decline of a glacial period, the same author records that, while America was passing through that ordeal, the ice-waters augmented the Mississippi until its average width was seventy-five miles where it is now a bare half-mile broad (*id.*, p. 475, and *Lyell's Principles*, Vol. I. p., 441).

To return to our own formations, we must not imagine that when once these leads were buried out of sight they remained for ever undisturbed. On the contrary, they have been scooped out and refilled repeatedly.

Captain Couchman describes some hills at Fryer's Creek as being covered in a "most erratic manner by a gravelly wash, which is as plentiful on the tops and flanks of the hills as on the floor of the gullies" (B. Smyth's *Goldfields*, p. 158). A. W. Howitt reports gravel beds which occur upon the Delegete at from 500 to 600 feet above the river (B. Smyth's *Goldfields*, p. 118), and also drifts of rounded quartz between the Clifton and Nicholson. "These not only cover the hills as surface, or form beds in the stream, but also, in places, constitute 'made' hills" (*Gold*, p. 681).

Ainsworth (mining surveyor) gives a description of a drift of slate and granite boulders and clay on the Never-mind Spur, Wood's Point, at an altitude of 1200 feet (B. Smyth's *Goldfields*, p. 87); and Hodgkinson, in a paper "On the Inter-Mitta and Campaspe Geology," mentions the occurrence of recent alluviums of water-worn schist, quartz, and slate on granite hills near the Campaspe mouth, which drifts, he says, "are not only at a considerable elevation, but must have been brought from very far-distant sources" (*Phil. Ins. T.*, Vol. VI.).

Krausé reports similar deposits of older pliocene date on hills near Stawell (Lock's *Gold*, p. 651).

From the condition of these alluviums, we can picture a time when the sea was receding from till-covered plains. As it withdrew the land surfaces became veined with creeks and rivers. These, as they wound down the gentle slopes, slowly scoured out the soft materials until, in time, gravel-capped ridges separated the several watersheds.

Meteoric conditions approximating more and more closely to those of this age then succeeded, and must have held sway for a long period, perhaps 80,000 years (Croll, *C. and T.*, p. 325). Ordinary fluvial action has, therefore, been the last and longest modeller of the surface. It has given the finishing touches, and, of necessity, all the superficial appearances indicate the sculpture of flowing water. The scour of the stream has dimmed the traces of all prior agencies; but if by the aid of experience gathered from other countries which have been glaciated we can look through the lighter outlines sketched on the rocks and sediments by aqueous action, we shall discern beneath them the touch of the heavier hand and the sharper chisel of frost and ice and snow.

Therefore we are stimulated to inquire whether the sister sciences can throw any side-lights upon the problem of the post-miocene glaciation of Victoria.

It appears to me that very valuable aid is available from these sources.

II.

Recent investigations have established the fact that the earth's climate, so uniform in character within historical times, varies very considerably if we take long periods into account. The climate known to man has been shown to be a mean between two extremes of heat and cold which have prevailed during previous epochs.

Dr. Croll has investigated the subject very fully, and the conclusions which he has formed have been accepted by such men as Archibald Geikie, the Inspector-General of the Geological Survey of Great Britain, and by Sir William Thomson.

He has shown that the earth's climate at any period depends upon a complex arrangement of circumstances. It is, of course, in the first place, dependent upon the amount of heat sent to it by the sun; but the effect of this, or its amount at any particular time, is modified by the form of the earth's orbit at that time, by the position of the earth in that orbit, by the precession of the equinoxes, the obliquity of the ecliptic, and greatly by the distribution of snow and cloud on either hemisphere. All these conditions are inconstant, although they change but slowly. And as their rates of alteration vary they sometimes coincide and augment their effects, whilst at other times they neutralise each other's influence more or less.

The earth's orbit varies from age to age. At this moment it is losing the elliptic form it had not very long since, geologically speaking, and it is becoming more and more circular. The limits of its variations are known. Fourteen million miles is the highest eccentricity to which it attains, and its lowest is about half a million. At the present moment its variation from a true circle amounts to three million miles. The result of this inconstancy is that the seasons, apparently so equally distributed throughout the year, are variable in length from epoch to epoch. The present eccentricity gives to us in the Southern Hemisphere a summer half-year seven days shorter than our winter half-year; but there have been periods when the difference amounted to thirty-six days, and, on the other hand, times when the difference was only forty-eight hours.

Indirectly the temperature of the earth is greatly affected by these variations in the length of the seasons; and when the winter of either hemisphere is prolonged by thirty-six days the earth absorbs less heat than it does now by one-fifth part (Croll, *C. and T.*, p. 56). Whenever the orbit attains to a high degree of eccentricity the climate of one hemisphere becomes intensely cold, while the other grows hot, moist, and winterless. The one which cools down is the one which has wintered in aphelion; it finds itself furthest from the sun just when it most needs its warmth. The other hemisphere enters on its warm season as it is approaching the sun, and it is heated up excessively in consequence.

Owing to the effects of precession, each hemisphere exchanges places and climates with the other about every 10,500 years, so that this period is the term during which either hemisphere can experience extreme heat or extreme cold. But the orbital eccentricity may last many times longer, and while it lasts the earth's climate will be marked by remarkable oscillations of temperatures between the two hemispheres.

The last epoch of high eccentricity commenced 240,000 years ago, and, having lasted about 160,000 years, came to a close 80,000 years since (Croll, *C. and T.*, p. 325). During this epoch each hemisphere experienced about seven oscillations of climate, passing through seven glacial and seven sultry periods. The winter of one hemisphere was always between eighteen and twenty-six days longer than its summer, while the other hemisphere had its summers from eighteen to twenty-six days longer than its winters. In consequence of this the temperature of the cold hemisphere was lowered from 29.5° to 37.7° F. below the present winter temperature (*C. and T.*, p. 320).

But the full effect of these changes was attained indirectly. The long warm period in one hemisphere caused its polar ice-cap to disappear after a time, and as it melted off one pole it accumulated around the other. Thus the earth's centre of gravity became disturbed; it shifted towards the loaded pole, and, as it moved, it drew after it the fluids of the globe—the sea, the plastic nucleus, if there be one, and perhaps the atmosphere. As the ocean readjusted itself to the new centre, by heaping up its waters around it, the low lands of that half of the globe were swamped, whilst the sea drained off the shallower littoral of the other, converting large areas of sea bottom into dry land.

Dr. Croll goes further, and taking the present rate of sub-aerial denudation as a measure of time, shows that there are excellent grounds for believing that the period of eccentricity just referred to corresponds with the last glacial epoch in the Northern Hemisphere, which occurred towards the close of the tertiary and the commencement of the quaternary periods, that is to say, during post-miocene times.

But if the Northern Hemisphere passed through a glacial period about that time, the Southern cannot have escaped; and the only question to be discussed to-night is whether Victoria was or was not within the range of its rigours.

Now, geologists have determined the range of glaciation in the Northern Hemisphere so well, that their conclusions will afford us great help in ascertaining the range of glaciation here.

Croll and others find that the polar ice-cap must have been two and a half miles thick at the least, and that it was probably vastly more, perhaps as much as twelve miles (*C. and T.*, pp. 377-81); that the ice was two and a half miles thick in Canada, and 2000 feet deep over Scotland (*C. and T.*, p. 452). One vast ice-sheet covered all Europe down to the latitude of the Thames; while far southward of 52 degs. N. latitude every mountain had its glacier system. The equatorial margin of this ice-cap was as irregular as an isothermal line on a chart, and in places it overlapped latitudes corresponding to that of Melbourne (*Great Ice Age*, p. 457). Therefore, there is nothing unlikely, in itself, in the statement that Victoria has been glaciated; and its probability is increased when we remember that all the lower lands of Australia must then have been submerged, whereby the northern interior, which now serves as a warming pan to our atmosphere, was exchanged for cool sea-water; that the north-west anti-trades would then be stronger and moister, and the south-west Antarctic Ocean drift would then be stronger and colder; that then every zone of temperature must have been shifted equatorward at least 10 degs., so that the wet west winds which now circulate below 40° S., and which feed the glaciers of New Zealand and Patagonia, would then blow up to 30° S., soaking with rain or mantling with snow the islands of Australia. For then Australia, partially submerged by the ocean rise, was an island, shaped like a jack-boot, with the Darling Downs for its uppers, the Howe for its heel, the Grampians for its toe, and the Adelaide ranges for its Sicily; while its long rocky length lay north and south, right athwart the course of the chilly, moisture-bearing winds.

In the other hemisphere the edge of permanent ice moved down from 77° N. to 50° N., or an advance of 27 degs. If a similar advance was made in this hemisphere the ice barrier must have been in 43° S., which is the latitude of Hobart. Nor is there anything extraordinary in this supposition, for New Zealand has even now, in the same latitude, a glacier which descends within 700 feet of the sea; while South America has, in 46° S., glaciers which dip into the sea and shed icebergs. If, therefore, the ice-barrier were then as near to us as 43° S., our coast would have been cumbered with bergs and floes, and the mountainous island of Australia must have been as cloaked with ice and snow as the Georgias are to-day. Australia might not be high and large enough to nourish a true continental ice-sheet, but every range would have its confluent glaciers, whose projecting feet might plough up the shallow foreshore.

According to Croll's calculations there must have been a lowering of the temperature, which would vary between 29.5° S. and 37.7 E. (*C. and T.*, p. 316). The present mean temperature of Victoria is 58° F. If we take this as a standard, and deduct the lower amount, the result will give us 3° below freezing point as the mean temperature of Victoria during the glacial epoch; and if we make our mean winter temperature, which is 49°, our standard, then the temperature would have a mean of 12° below the freezing point, and that of Sydney would be about 7° below—that is to say, the temperature would be that of South Greenland in winter time. We must not forget that at this time there was a lofty sandstone plateau of miocene age where our Dividing Range now stands, and that these highlands probably had an altitude of at least 2000 feet greater than the present peaks. The glaciers these extensive chilly heights would breed may have been the main factors in filing down their even crowns into the existing series of sierras (Howitt, *R. S. T.*, Vol. XVI.). The *débris* of these peaks may have supplied the material to build up the sandstone plateaux of Central Australia, whose flat surface of cretaceous age was in those times submerged, and which, it is probable, was covered with brackish ice-waters of shallow depth, loaded with sediment, running northwards in strong currents. Let us see what geological evidence we have to countenance these theories.

It will be admitted, as a fair inference, I do not doubt, that if the other lands situate in similar latitudes in this hemisphere can be shown to have passed through a glacial period about the close of the tertiary period, Victoria cannot have escaped the same experience.

If, then, we turn to New Zealand, we shall find the geologists of that colony recording the existence, during the epoch in question, of glaciers so much greater than the present ones, that, where the largest to-day does not exceed from 15 to 18 miles in length, there then was at least one 112 miles long (V. Haast's *Geo. of Canterbury*, p. 385).

In South Africa we find evidences of a similar climatal condition. All over British Kaffraria and Natal—that is, between 28° S. and 34° S.—dome-shaped rocks, enormous erratics, unstratified boulder clays, and conglomerate beds are abundant. There are ice-grooved rocks and boulders, the latter being found in auriferous leads at the Moonlight Diggings; and also long, winding kames running up the valleys (*G. S. J. Stow*, 1874, pp. 588-658; XXVII., p. 535; and XVIII., p. 8).

It will be noticed that these occur nearer to the equator than is either Sydney or Bourke.

In South America we find glacial drift at low levels up to 18° S., and Agassiz reports similar deposits in Brazil. David Forbes saw deeply furrowed rocks and other characteristic evidence on the Cordilleras within the tropics, and far below the present snow-line (*Gold*, p. 216). Darwin saw immense moraines in Central Chili (*Or. Species*, p. 335), and also widespread deposits of boulders, gravel, and clay, up to 1400 feet above the sea level, in the interior of Patagonia (*Geo. Obs. on South America*, pp. 10-19), and he assigns them to pliocene or pleistocene times.

I think that these facts should fairly suffice to establish the occurrence of a glacial climate throughout the now temperate regions of this hemisphere, and during post-miocene times. If this be so, it is hard to see why Victoria should have escaped the same experience; and I think that we are entitled to this opinion whether the local evidence is accepted as sufficient or not.

But there is another of the sciences which we can call in to aid us in fathoming the problem.

If we turn to the natural history of this hemisphere, we find that the present geographical distribution of plants and animals absolutely requires a glacial period to account for its anomalies.

Darwin is emphatic enough on this point. He tells us that "we must bear in mind the occurrence in both hemispheres of former glacial periods, for these will account for the many quite distinct species inhabiting the same widely separated areas, and belonging to genera not now found in the intermediate torrid zone. . . . In the regular course of events, the Southern Hemisphere would in its turn be subjected to a severe glacial period, . . . and then the southern temperate forms would invade the equatorial lowlands. The northern forms which had then been left on the mountains would now descend and mingle with the southern forms. Thus we would have some few species identically the same in the northern and southern temperate zones, and on the mountains of the intermediate tropical regions" (*Or. Species*, ch. XII., pp. 339, 340).

When we seek confirmation of these views of Darwin's, we find it. Baron von Mueller reports the discovery of European species of plants upon our mountains, and Dr. Hooker points out that certain peculiarly Australian forms of vegetation now live upon the heights of Malacca, India, and Japan. Further, there are northern forms of fish and seaweed living upon our coasts, although absent from the seas which intervene between Australia and the habitat of the other members of these families.

No naturalist has given more consideration than has Wallace to the distribution of the flora and fauna of this quarter of the globe, and his statements are entitled to attention. If we compare the distribution of our plants, as he describes its occurrence, with the plan of distribution which we should expect to succeed to a glacial and submerged period, we must be struck with the remarkable degree of accord which they present.

If our climate be recovering from a glacial period, as we believe that it is, then all the temperate zones will be moving northward toward the equator, the warmer ones in front, the colder ranked behind. As this occurs the flora and fauna follow them, keeping slightly in the rear; for each temperature as it withdraws from a district has to pull after it the forms of life peculiar to it, and the different climate which follows on its heels cuts off the laggards and stragglers before they fall very far in the rear of the main body. Now, according to Wallace, this process is going on in Australia. He tells us that our tropic flora is wanting in several important tropic families, which are, singularly enough, to be found in our temperate regions. Such are the *Dilleniaceæ*, *Liliaceæ*, *Polygaleæ*, and many others (Wallace's *Australia*, 222). The presence of such tropic forms in these temperate regions shows that not long since a tropic climate reigned there, and that it has moved away equatorward faster than the vegetation could follow it. The tropic regions to the north of them, and into which they have not yet passed, is poor in vegetal life, because it has only recently emerged from the sea, and the immigrants from the south, and proper to it, have been slow in coming. Again, such a submergence as we suppose accompanied a glacial period would cut Australia into two parts at least, an east and a west island; and the marked difference between the eastern and western floras accord with such a severance. Out of four hundred and fifty known species of acacia, melaluca, and eucalyptus, not a single one is common to the two provinces. "The large genera common to both sides of the continent are," says Wallace, "wonderfully distinct" (Wallace's *Australia*, 46).

Furthermore, as the retiring tide leaves behind it pools which indicate levels recently attained to, so a retiring temperature leaves in its wake its flotsam and jetsam to attest its former presence in latitudes now behind it. As the temperature of a locality rises, some of its flora and fauna may remain, and yet save themselves from extinction by having access to higher lands. Thus it is that the Antarctic genus *Drimys* still lives far up on the lofty heights of New Guinea (Wallace's *Australia*, 444) and of Borneo (*ib.*, 353), after its congeners have wandered southward some thousands of miles, and that thirty-eight species of European plants are found on the mountain peaks of Victoria wherever they rise over 5000 feet in altitude.

Similarly, as the temperature falls, some plants secure themselves by retreating to sheltered spots, where they survive after their neighbours have either moved on or been destroyed. We have such a relic of torrid times in Victoria in the cabbage-palm, which is found in the warm, moist, and well-sheltered gullies of Gippsland, although outside of these natural hot-houses it is sought in vain until we reach the tropics, now its natural home (Wallace's *Australia,* p. 130). How could this heat-loving palm-tree have marched over the Dividing Ranges into Gippsland, unless a rise in the temperature at some earlier period had favoured the passage?

Again, we must call in glacial influences to account for the disappearance of the huge beasts which tenanted Australia in bygone times.

Wallace tells us that "we live in a zoologically impoverished world, from which all the largest, fiercest, and strongest forms have recently disappeared" (*Geo. Dist. P. and A.*, p. 150), and he connects this remarkable fact with the refrigeration of climate during the glacial period.

Professor Phillips also connects the extinction of the great carnivora and pachydermata with the same cause, while Professor A. Geikie takes a similar view *(Text Book,* p. 894). It must at once occur to every mind that our great marsupials died out early in the quaternary epoch, if not before then. If it was this cold which destroyed the monsters of the other hemisphere, it was probably the same cause which destroyed those of this half also. Their extinction at this particular point of time indicates to us a severe fall in the temperature of Australia.

The next question we shall have to consider is that of secular oceanic oscillation. As we have already mentioned, Croll and others believe that the loaded pole of a glacial period shifts the centre of gravity and pulls around it the waters of the ocean. Taking his figures as a basis, an Antarctic ice-cap extending only 55° S. latitude, and having a slope of only half a degree, would cause the sea level to rise 1100 feet at the South Pole, and about 900 feet in the latitude of Melbourne (Croll, *C. and T.*, p. 389).

Now, any such a rise within the period we are discussing would leave behind it traces which we could recognise; and as a glacial epoch and land submergence are connected together in nature, the evidence which establishes the occurrence of the one may be brought in to support that of the other.

A rise of 900 feet on the part of the ocean would convert Australia into a long, narrow, mountainous island, with an archipelago to the west of it, the former representing Eastern and the latter Western Australia.

Now, we have in Victoria marine deposits of post-miocene age up to and over the altitude of 1000 feet.

Krausé, in his report upon the Otway Ranges, describes extensive marine deposits of pliocene age up to 1200 feet above the sea (*Geo. Sur. Rep.*, 1874, p. 103); and in another report he has described horizontal tertiary sea beaches on the flanks of the Grampians at an altitude of 900 feet (*id.*, p. 124), and another near Ararat at 1100 feet (*G. S. R.*, Oct., 1874).

At Creswick there are pliocene marine deposits at elevations which vary between 1420 feet and 1720 feet (Lock's *Gold*, p. 931).

A. W. Howitt has described similar tertiary deposits near Mount Taylor, at an elevation of about 600 or 700 feet (B. Smyth's *Goldfields*, p. 123).

At Portland we get further evidence. The beach cliffs are of a kind of pliocene chalk, which is known as *Globegerina ooze* because it is full of the foraminifera *Globegerina bulloides* and *Orbulina universa*, which do not live in waters of less depth than 1500 to 1600 feet. They are a well-determined form of deep-sea life. To expose these deep-sea beds above water the sea level must have fallen 1500 to 1600 feet within pliocene times, and this amount of alteration in the relative level of sea and land fairly agrees in degree with the evidence from the mountains (Woods' *Geo. of Portland*, pp. 14-16).

Again, on the flanks of Tower Hill, near Warrnambool, a well was sunk 123 feet. The first 63 feet was through volcanic ash, and the last 60 feet was through clay. At this depth the skeleton of a dingo was found. The dingo is believed to have been introduced to Australia by man; and in any case it is a late introduction. Yet after it died the ocean covered that part of the country, and had time to deposit many feet of sediment before it retired (*Q. J. G. S.*, 1857, p. 227).

The Rev. Julian Woods has described a tertiary marine limestone on Tapley's Hill, near Adelaide, which occurs 1000 feet above sea level; and another observer, in a paper contributed to the Adelaide Philosophical Society (*A. P. S. J.*, 1877-9), states that there are traces of submersion to 800 feet in late tertiary times.

Western Australia has risen above the waves since the pliocene era closed, but I cannot ascertain that any measurements have been recorded.

As to New Zealand, Hutton declares himself strongly convinced that the Canterbury Plains, now 1700 feet above the beach, were under the sea at the commencement of the pleistocene period (*Geo. Sur., N.Z.*, 1873-4, p. 58); and, although Dr. von Haast disputes this conclusion, it harmonises with the other evidence. Besides this, the latter geologist admits that New Zealand was submerged to a considerable depth during pliocene times (*Geo. of Canterbury*, p. 373).

From South Africa we learn that pliocene shells are found in deposits high above the sea level throughout Kaffraria, but the exact height is not given (Stow, *Q. J. G. S.*, XXVII., p. 544).

Turning to South America, we find that on the east coast, from Cape Horn up to 33° S. latitude, there are old sea margins at seven different heights, the highest being 1400 feet above sea level, and these are of pliocene or later age. Darwin is of opinion that during this period this part of the country was an archipelago, a conclusion strangely similar to that which we have already arrived at concerning Australia at about the same time (*Geo. Notes S. Am.*, p. 10).

On the west coast there are margins up to considerable elevations; but their evidence is unreliable owing to the volcanic disturbances on that coast which have interfered with the levels.

This is the evidence that I have to offer in favour of the view that within post-miocene times Victoria has been dipped beneath the waves. The exact depth to which she sank it is difficult to fix, for there have been several rises of the sea, and each should have left its mark. As it is unlikely that any two were alike in height, and as most of the traces have disappeared, those remaining probably represent the relics of not one, but of several rises. And further than this, there are slow earth movements which ought to be taken into account, if they can be ascertained, when we endeavour to fix the exact amount of alteration in the levels. The broad fact remains, however, that the geological evidence fits still further into that drawn from so many other sources, and it points to a general submergence of the land throughout the latitudes south of 33° S.

The last evidence that I shall submit to you is that of the seven or eight warm periods which were intercalated between the seven or eight cold ones which occurred during the last epoch of high eccentricity. We saw that each of these periods had a length of a little over ten thousand years. The cold periods have left behind them many inorganic traces of their occurrence. The warm, interglacial periods, however, produced a luxuriant growth of vegetation, and the remains of this are fairly plentiful.

Thus, there are the fossils of the Haddon lead, which Mueller declares to be indicative of a hot, humid, equable climate during the newer-older pliocene period, and these are closely adjacent to a deep boulder bed, indicative of glacial times, the proximity of which tells us of a quick succession of climatic changes.

At the mouth of the Cumberland Creek, near the Otway, there is a lignite deposit, the product of warm, moist, equable times, closely overlain by a conglomerate of sand, gravel, and huge boulders, relics of the other extreme (*Geo. S. Rep.*, p. 96). Similar deposits, in close juxtaposition, occur in considerable numbers throughout the colony, and notably in the superficial alluviums of Gippsland (Selwyn, *Phy. G. Vict.*, p. 79). On the heights of Kiandra we have lignite intercalated between conglomerates of pliocene age.

Baron von Mueller has discovered evidence of these climatic fluctuations in three complete changes in the character of Australian vegetation, all of which have occurred since the commencement of the pliocene period. The fossil remains show that when the older pliocene deposits were being laid down this country had a lauraceous flora. With the newer pliocene this disappeared, and in its stead plants of the meliaceous order became in the ascendant, and had associated with them a richly tropic flora. This may have been the period which yielded the palm frond discovered fossilised in Tasmania (*Geo. S.*, Vol. II., p. 24); and our cabbage-palms, in Gippsland, also may trace back their introduction to this era.

With the close of this period meliaceous plants disappear completely from this continent; the tropic forms move northward; and in pleistocene times myrtaceous plants come upon the scene for the first time, and eventually give to our scenery the peculiar and marked character that it now has (*G. S. Vict.*, Vol. II., 29).

When we reflect upon these three entire and rapid changes in our vegetation, we can find no explanation that will account for them as the glacial epoch will, with its climatic fluctuations, its sea oscillations, and its frequent breaking up and reuniting of our continent.

But the fact that fossils indicative of warm temperatures have been found in formations of pliocene and more recent times has been used to prove the impossibility of a glacial epoch having occurred in Australia. We must, therefore, devote some consideration to the arguments and evidence of those who hold views which differ from those set forth in this paper.

III.

The Rev. Julian Woods, in the year 1867, contributed to this Society a paper designed to prove that there had never been a glacial period in Australia within tertiary times.

He based his conclusions upon the following grounds:—Firstly, because our early tertiary fossils have a tropic facies; secondly, because our miocene shells are identical with species now living under the equator; thirdly, because South Australian pliocene shells are also identical with tropical species; fourthly, because a Tasmanian pliocene formation has been found with a fossil palm in it; fifthly, because the quaternary shells of Western Australia present a tropic aspect.

Upon the strength of such evidence he decides that Australia has not experienced a glacial epoch within tertiary times, but that, on the contrary, the climate was very warm in early tertiary times, and has been cooling down ever since.

In criticising this evidence we have a great advantage over the rev. gentleman, because we to-day understand the nature of glacial periods much better than we did fifteen or twenty years ago, when he wrote.

In consequence of the greater acquaintance with the subject which geologists now have, we know that each glacial epoch contained within it a set of warm periods as well as of cold ones, and that the tropic forms which he has relied upon would flourish during any one of them. These hot and cold periods were complimentary to each other in a glacial epoch, and their occurrence, as testified to by these shells, is strongly confirmatory of the occurrence of such an epoch.

If we take the evidence and examine it separately, we find that it confirms this view; for instance, Woods mentions the fossil shell *Fusus colossus,* found in Western Australia, and points out that it is now represented only by species confined to the tropics. Therefore he tells us that colony cannot have experienced a cold period. I contend that the evidence proves no more than this, that a warm climate prevailed there when that fossil flourished, and that its occurrence is not inconsistent with the prevalence of a cold climate shortly before and shortly afterwards.

In a South African pliocene formation a fossil (*Venericardia*) is abundant. The shell-fish has abandoned the coast, and is now found only within the tropics. According to Mr. Woods, this should be evidence that South Africa has never been subjected to an arctic climate; and yet immediately below the limestone containing this fossil a deposit of till, scratched rocks, and other glacial indications are found (*C. and T.*, p. 242).

Again, the tropic shells of South Australia are in formations which have for neighbours glacial drifts and grooved rocks. Indeed, we need not go further than Mr. Woods' own writings to find counter arguments. That gentleman has carefully described the crag formations of that colony, and he has identified them with the typical crag of Norfolk (*Geo. Obs. of South Australia,* p. 178). Now, this crag indicates a cold climate. Lyall says that "the fauna of the upper crag is very arctic in character" (*Principles,* Vol. I., pp. 197-9). The only deduction which the evidence warrants is that the climate was fluctuating, and passing quickly from extreme to extreme, as it does in every glacial period. Dr. Duncan confirms this view, after a careful examination of the fossiliferous limestone of the cliffs of the Australian Bight; for he says that its contents indicate a change of climate, an alteration in the distribution of marine animals, and an elevation of the land (Wallace's *Australia,* p. 78).

I feel, therefore, that the evidence which Mr. Woods marshals in array against the occurrence of a glacial climate here may be dismissed as inconclusive.

IV.

Let me ask, What interpretation can be put upon all the different facts which I have thrown together if the glacial theory is rejected?

We shall have to believe that since the pliocene era commenced Victoria has been elevated and depressed to a considerable extent at least five or six times. Surely these great movements would have involved a degree of flexure of the earth's crust in these regions such as must have left behind it great traces in the tertiary deposits.

And yet, when we search for such traces we cannot find any. Undisturbed sedimentary deposits overlie the upturned edges of our palæozoic rocks.

Sir Andrew Clark in 1855 reported to our Government that the "tertiary beds" of the southern parts of Victoria "are always (a few cases of local disturbance excepted) either horizontal, or dip at very small angles—viz., 1 deg. to 5 degs." *(Geo. Sur. Vict.*, 1855, p. 9).

The limestone pliocene deposits of Mount Gambier, S.A., are reported to be perfectly horizontal also. Woods tells us that an area of many thousand square miles is "occupied by one formation without alteration of level, break, or interruption. . . . The strata occur in nearly every case parallel with the horizon" *(Geo. Obs. S. A.*, pp. 59, 60).

The tall cliffs which wall in the Great Australian Bight for hundreds of miles are reported to be fairly level throughout the whole distance.

A. W. Howitt, writing of the Murray Plains in an official report, remarks that "the elevation and depression of the land from far back in tertiary times have been equable and regular over wide districts" (*Geo. Sur. Vict.*, Vol. II., p. 80).

If we turn our eyes to South America we find exactly the same condition of things.

Although the east coast has no less than seven elevated sea beaches, the topmost one being 1400 feet above the ocean, there is no flexure to indicate movements of the earth's crust, and no dislocation of the formations. Darwin tells us that the beaches preserve an altitude which does not vary 10 feet throughout a distance of 700 miles. They excited on his part expressions of the utmost wonder from their extraordinary degree of horizontality. On the west coast, where volcanic action is elevating the surface, the raised beaches can be traced for a distance of 2000 miles; but they, on the contrary, show the utmost irregularity in altitude, and are much "thrown" in parts (Darwin's *Notes on Geo. of So. Am.*, pp. 53-55).

The evidence of frequent alterations in the relative levels of land and sea in the Southern Hemisphere is as abundant as that of flexure and fracture in the superficial deposits of the crust is rare.

Oscillations of the ocean, due to cosmical causes, better fit the conditions; they explain all the facts more simply, and they harmonise with the glacial theory.

I have now completed the task I had set myself, and hasten to conclude.

We have seen that, owing to various obscure causes, Victoria must have its climate lowered at various times. On the last occasion a miocene plateau, of great height and undetermined area, was ground off the face of the country by glacial ice. Its non-auriferous sandstone yielded the valueless early washes of our goldfields (Selwyn's *Geo. Obs. Vict.*, p. 22). The poor upper silurian shales and slates were next reached, and scoured away over wide tracks, and these yielded the inferior washes of middle date; and last, the rich lower silurian rock was uncovered, and literally quarried away by wedge of frost and chisel of ice, and the *débris* was reduced to boulders, gravel, sand, and clay in the glacier battery. These products, ground-sluiced by the ice-waters, remain behind as the golden washes of the latest period.

We have seen that these operations were not continuous, but were interrupted by periods of warmer temperature. With these changes the ocean oscillated, its waters now rising until Australia was an archipelago, and anon sinking until Bass's Straits were dry land, and a promontory stretched its long horn far southward of Tasmania. And while these operations were proceeding the flora and fauna were being shifted from point to point, exterminated, renewed, and varied in a remarkable manner.

Such is a bald sketch of the picture which presents itself to the mind as one reviews the evidence by the light of the geological revelations of the Northern Hemisphere. It appears to me that a glacial climate in Victoria during post-miocene times will account for many local phenomena which are not explained by the fluvial theory, and will render intelligible many of the peculiarities of our deep leads and of our alluviums.

Art. II.—*The Recent Red Sunsets.*

By Professor Andrew.

[Read 13th March, 1884.]

Art. III.—*The Phanerogamia of the Mitta Mitta Source Basin.*

Article II.

By James Stirling, F.L.S., Omeo.

[Read 13th March, 1884.]

CHORIPETALEÆ HYPOGYNÆ.

Ranunculaceæ (A. L. de Jussieu).

Clematis microphylla (De Candolle).—On the steep ranges west from junction of Livingstone Creek and Mitta River, on argillaceous schist formation, a variety, Stenophylla, is occasionally met with. This species covers many shrubs with its clusters of cream-coloured blossoms; it ascends to 3000 feet elevation; on the moist southern coastal regions in Mitchell River source-basin it is more abundant. The same remark applies to C. aristata.

Ranunculus rivularis (Banks et Solander).—This variable species is very common on damp situations within this area, particularly on Wilson's Creek, near Omeo; mica-schist formation; on the alluvium at Omeo Plains and on the Victoria River, ascending in the valley of the latter to 4000 feet.

Ranunculus parviflorus (Linné).—On the marshy sub-alpine flats near heads of Livingstone Creek this small-flowered species is abundant, but it occurs also on damp situations near Omeo. It is very much affected by a fungus—æcidium ranunculacearum.

Ranunculus aquatilis (Linné).—The races near Omeo used for mining purposes are frequently so much choked up with the vigorous growth of this species and some species of Chara and Conferva as to require periodical cleaning; nearly all the shallow waterholes about Omeo are more or less full of a growth of this species.

Caltha introloba (F. v. M.).—This dwarfed, stemless herb is restricted to the snowy regions at elevations of 5000 to 6000 feet at the source-runnels of the Cobungra River, on the edge of the basaltic plateau, Bogong High Plains; also at Mount Hotham, 6015 feet; Mount Latrobe, at 6200 feet elevations.

DILLENIACEÆ (Salisbury).

Hibbertia stricta (R. Brown).—This widely-distributed species is found on the sandy soils and gravelly banks near the junction of Livingstone Creek and Mitta Mitta River at 1600 feet elevation.

Hibbertia linearis (R. Brown).—Common along with H. diffusa on the open sunny northern slopes of mica-schist formation near Omeo Plains, at 3000 feet elevations.

MONIMIEÆ (A. L. de Jussieu).

Atherosperma moschatum (Labillardière).—See pt. 1, p. 5.

Hedycarya Cunninghami (Tulasne).—This is the "Rurnai" of the Gippsland aborigines, used by them for procuring fire—twigs being rubbed together for that purpose.

CRUCIFERÆ (A. L. de Jussieu).

Barbaraea vulgaris (R. Brown).—Frequent on damp cultivated ground, and on springy spots along the western affluents of Livingstone Creek, on metamorphic-schist formation; at elevations of 1600 to 3000 feet.

Arabis glabra (Crantz).—At elevations of 2000 to 3000 feet on Livingstone Creek, at higher elevations on the Cobungra and Victoria Rivers; generally on bluffs or rocky sidelings of granitic or gneissic schist.

Cardamine dictyosperma (Hooker).—In moist crevices of felspathic rocks, Wilson's Creek, near Omeo; 2500 feet elevation.

VIOLACEÆ (De Candolle).

Viola Caleyana (G. Don).—Common on Hinnomunjie Flat, on alluvium, and on the Livingstone Creek ranges; ascends to 3200 feet, and probably to higher levels.

Hymenanthera Banksii (F. v. M.).—The marked difference between the lowland and alpine form of this shrubby species renders it an object of interest to the phytographer; at elevations of from 3000 to 5000 feet it forms a procumbent shrub, hard-wooded and strongly spinous, the berries larger, and paler purple in colour than the arboreous lowland form.—See pt. 1, p. 5.

PITTOSPOREÆ (R. Brown).

Marianthus procumbens (Bentham).—Is occasionally met with on the open spurs from the Dividing Range toward the head of Livingstone Creek, where the metamorphosed schists merge into the Silurian slates; at elevations of 3000 to 4000 feet.

Billardiera longiflora (Labillardière).—In scrubby situations along the Dividing Range, on Silurian formation, particularly where there is much vegetable mould, climbing over branches of Lomatia ilicifolia and Pittosporum bicolour; it ascends, near Mount Phipps, to 4000 feet.

DROSERACEÆ (Salisbury).

Drosera auriculata (Backhouse).—On damp, grassy, and mossy depressions at the summit of Mount Sisters; 3000 to 3600 feet elevation; in metamorphic or intrusive granite formation.

Drosera peltata (Smith).—Common on damp pastures near Omeo, at elevations of from 2000 to 3000 feet. In an interesting paper read before the Field Naturalists' Club, by my friend Mr. Sullivan, of Moyston, the fact of the absorption of insect substance by the leaves of our Australian Droseraceæ is questioned, and the results of experiments detailed. I have now to state, that recent observations made by me by the aid of a powerful microscope on the leaves of D. peltata (and upon which insects had been smothered by the infolding of the tentacular hair and the secretion of a viscid fluid from their terminal glands), clearly indicated absorption taking place through the cells forming the cuticle of the leaf, apparently by a process of endosmose. The insects were representatives of the Diptera.

HYPERICINÆ (J. de St. Hilaire).

Hypericum Japonicum (Thunberg).—All over the undulating ranges, near Omeo, on mica-schist formation; on the Omeo Plains, alluvium, and ascending on the flats along the upper course of the Victoria River; granitic areas, up to 4000 feet.

Polygaleæ (A. L. de Jussieu).

Comesperma volubile (Labillardière).—This twining species is more common on the coast regions of the Mitchell River basin; apparently rare on the Mitta Mitta affluents. A few plants are met with on the Dividing Range, near Mount Phipps, in scrubby localities of Silurian formation, at elevations of 3000 to 4000 feet.

Comesperma ericinum (De Candolle).—Very abundant on the auriferous areas; Dry Gully near Omeo, particularly on stony northern slopes, near junction of intrusive granite and metamorphic schists; at 2000 to 3000 feet elevations.

Tremandreæ (R. Brown).

Tetratheca ciliata (Lindley).—Sparsely distributed on sandy soils near the head of Livingstone Creek, at 3000 feet elevations; more abundant in the Wentworth Valley; its bright carmine-coloured petals render it easily distinguishable amid its sombre-coloured foliage. It is extremely sensitive to moisture, closing its petals (like some species of Helipterum and Helichrysum) on damp or rainy days, and opening again with the sunshine.

Rutaceæ (A. L. de Jussieu).

Zieria Smithii (Andrews).—See pt. 1, p. 7.

Boronia Algida (F. v. M.).—This shrubby species is abundant at high elevations—for instance, on the sources of Big River, and on the rocky, rolling ridges towards Bogong High Plains at 5000 to 6000 feet elevations; also near the summit of Mount Hotham. It appears to be governed in its distribution more by climatic conditions than by character of soil.—See pt. 1, p. 7.

Eriostemon Crowei (F. v. M.).—Var. Exalata.—On granitic areas, near the junction of the Cobungra and Big Rivers; at about 3000 feet elevation.—See pt. 1, p. 7.

Eriostemon phylicifolius (F. v. M.).—This somewhat dwarfed species is found growing on the quartz-porphyry formation near Mount Sisters at elevations of about 3000 feet, and on Dividing Range toward Mount Tambo.

Eriostemon ozothamnoides (F. v. M.).—On the river gravels at the junction of Livingstone Creek and the Mitta Mitta River, thence ascending along the margins of the

Big River, Cobungra River and Bundara River; on granitic and argillaceous schist areas up to 5000 feet. The plant is very much stunted at the higher elevations.

Eriostemon trachyphyllus (F. v. M.).—Common on Silurian soils along crest of Dividing Range at heads of Livingstone Creek; 4000 feet elevation; more abundant and gregarious on the upper sources of Wentworth River, there forming dense scrubs, 20 feet high, to the total exclusion of other vegetation.

GERANIACEÆ (A. L. de Jussieu).

Geranium Carolinianum (Linné).—Abundant near Omeo on the soft mica-schist areas; up to 3000 feet. Baron von Mueller thinks that the Australian plant might be kept distinct as G. pilosum (Forster).

Oxalis corniculata (Linné).—Common all over the lower ridges of the eastern watershed of the Livingstone Creek; up to 3000 feet.

EUPHORBIACEÆ (A. L. de Jussieu).

Poranthera microphylla (Brongniart).—All over the area this widely-spread species is abundant. On the mica-schist formation near Omeo it attains a height of only 3 or 4 inches; but on the Silurian ranges near Grant it frequently grows to a height of 10 to 12 inches.

Micrantheum hexandrum (J. Hooker).—A robust shrub 10 to 12 feet high; at the junction of Livingstone Creek and Mitta Mitta River.

Bertya Cunninghami (Planchon).—In similar locality to M. hexandrum, and on lower levels along Mitta Mitta River.

CASUARINEÆ (Mirbel).

Casuarina quadrivalvis (Labillardière).—This species, so common in littoral regions in the upland, is here met with in the granite area of the Mount Sisters, near Omeo Plains, at 3000 feet elevation.

SAPINDACEÆ (A. L. de Jussieu).

Dodonaea viscosa (Linné).—The var. attenuata is common on the Mitta Mitta at Hinnomunjie Flat on tertiary gravels; the leaves have a sour and bitter taste.

Stackhousieæ (R. Brown).

Stackhousia pulvinaris (F. v. M.).—A dwarfed species most abundant on the basaltic (tertiary) tablelands, Paw Paw and Precipice Plains, 4000 feet elevation, and on the ledges of the higher Bogong High Plains, at 5000 feet.

Portulaceæ (A. L. de Jussieu).

Claytonia Australasica (J. Hooker).—In cliffs of granite-porphyry rocks on summit of Mount Brothers, north of Omeo Plains, at 4600 feet elevation.

Caryophylleæ (Linné).

Stellaria multiflora (Hooker).—In fern-tree gullies of the Dividing Range, near Tongio Gap, at an altitude of 3800 feet.

Colobanthus Benthamianus (Fenzl).—On the highest Alps only.

Scleranthus biflorus (J. Hooker).—At higher elevations on the Victoria and Cobungra Rivers up to 5000 feet. S. minaroides occupies places 5000 to 6500 feet high on the sources of the Mitta Mitta.—See pt. 1, p. 9.

CHORIPETALEÆ PERIGYNÆ.

Leguminosæ (Haller).

Oxylobium ellipticum (R. Brown).—At the head of Benambra Creek; on stony ridges; Silurian formation; at 3800 to 4400 feet elevation.

Oxylobium alpestre (F. v. M.).—In similar situations with O. ellipticum, but more abundant on the other side of the Limestone Creek; on the porphyritic rocks of Mount Cobboras, at about 6000 feet elevation.

Daviesia corymbosa (Smith).—Abundant on the warmer northern slopes of Dry Gully watershed, near Omeo; on metamorphic-schist formation; at about 3000 feet elevations.

Pultenaea daphnoides (Wendland).—On ridges of the Dividing Range, forming the eastern watershed of the Livingstone Creek; sparsely distributed on heathy localities at elevations from 2600 to 6000 feet; more abundant on the Tambo River, towards the coast region.

Pultenaea subumbellata (Hooker).—On the Dividing Range, toward Mount Hotham, at about 4000 feet elevations; generally on mica-schist formation.

Bossiaea microphylla (Smith).—On the granitic area near the head of Livingstone Creek, at 3000 to 4000 feet elevation, but more abundant in the Dargo River Valley; at lower levels from 1000 to 2000 feet, on Silurian areas.

Bossiaea prostrata (R. Brown).—Common on the undulating ranges around Omeo, especially in the neighbourhood of felspathic intrusions.

Hovea longifolia (R. Brown).—A robust bush, at the junction of the Livingstone Creek and the Mitta Mitta River, attaining a height of 12 feet; ascending along the banks of the Cobungra and Big Rivers to 4000 feet.

Lotus australis (Andrews).—More abundant on the sub-alpine ridges east of Victoria Plains.—See pt. 1, p. 10.

Indigofera australis (Willdenow).—Nowhere gregarious within the area, but met with almost at all elevations up to 5000 feet. The purgative properties attributed to this plant elsewhere are not so strongly marked here.

Swainsona phacoides (Bentham).—On the banks of Day's Creek, near Omeo, in the neighbourhood of quartzitic schists; prevalent.

Glycine clandestina (Wendland).—Abundant on the eastern watershed of the Livingstone Creek, twining over low shrubs; ascends to 4000 feet elevations.

Kennedya monophylla (Ventenat).—This pretty creeper is very abundant all over the area under the name of "Native Sarsaparilla;" it is said to possess medicinal properties, the roots being used to make a tonic beverage; ascends to 5000 feet, as well on grass lands as on rocky slopes.

Kennedya prostrata (R. Brown).—Sparsely distributed on the Omeo Plains tableland, and on the ranges near Omeo; generally at elevations from 2000 to 3000 feet.

Acacia siculiformis (Cunningham).—Found on granitic areas along the margin of the Big River; up to 4000 feet elevations.—See pt. 1, p. 11.

Acacia juniperina (Willdenow).—On coarse, gritty, and sandy soils; decomposed from intrusive granite, near the sources of Livingstone Creek; at 3000 to 4000 feet elevations.

Acacia lunata (Sieber).—At the junction of the Livingstone Creek and the Mitta Mitta River; on tertiary gravels and alluvium.

Acacia penninervis (Sieber).—Forms on the crest of the Dividing Range; at the head of Livingstone, and on the Wentworth River falls a dense scrub; most abundant on Silurian areas; at 2000 to 4000 feet elevations.

Acacia dealbata (Link), "silver wattle."—On undulating Ranges, near Omeo; closely allied to A. decurrens.

ROSACEÆ (A. L. de Jussieu).

Acæna ovina (Cunningham).—A common herb on the Omeo Ranges, where it attains a height of 2 feet; ascending on the metamorphic-schist formation to 4000 feet.

CRASSULACEÆ (De Candolle).

Tillaea verticillaris (De Candolle).—Common on the dry gneissic schists near Omeo; on crevices of these rocks; ascends to 4000 feet elevations.

SALICARIEÆ (Adanson).

Lythrum Salicaria (Linné).—On Morass Creek, near Omeo Plains.—See pt. 1, p. 12.

HALORAGEÆ (R. Brown).

Haloragis teucrioides (A. Gray).—Common on the granite area near Tongio Gap, at 2600 feet, and on mica-schist ranges near Omeo.

Myriophyllum pedunculatum (Hooker).—On the mossy beds at sources of Victoria River, at about 4000 feet elevations, and in water races near Omeo.

MYRTACEÆ (Adanson).

Bæckea Gunniana (Schauer).—On the eastern slopes of the Bogong High Plains; along watercourses at about 6000 feet elevation.—See pt. 1, p. 12.

Leptospermum attenuatum (Smith).—Common on the Silurian soils near the Mitta Mitta River, at about 2000 feet elevations, and on the Livingstone Creek; in mica-schist formation at higher elevations.

Kunzea peduncularis (F. v. M.).—On source-runnels of the

Bundara and Big Rivers; in swampy localities at 4000 to 5000 feet.

Eucalyptus Gunnii (J. Hooker).—This species was named by me incorrectly in the first list as E. amygdalina; and the alpine species, E. pauciflora, as E. alpina. This correction in the nomenclature is necessary to be here given, as misapprehension might arise as to the distribution of E. alpina, which, as Baron von Mueller informs me, is restricted to the summit of Mount William, in Victoria.

Eucalyptus hemiphloia (F. v. M.).—See Part I., p. 13, as E. melliodora.

Eucalyptus piperita (Smith).—See Part I., p. 13, as E. fissilis.

Eucalyptus stellulata (Sieber).—Locally known as "Black Sally."—See pt. 1, p. 14.

Eucalyptus amygdalina (Labillardière).—This species is abundant in moist, southerly slopes, along with E. globulus; ascending to fully 4000 feet; on metamorphic-schist formation.

Rhamnaceæ (A. L. de Jussieu).

Pomaderris vacciniifolia (Reisseck).—Confined to the mica-schist bluffs of Livingstone Creek, near Omeo; elevation of 2100 feet.

Umbelliferæ (Morison).

Azorella cuneifolia (F. v. M.).—On the spagnum beds at the head of the Victoria River; in basaltic formation (tertiary); at elevations of 4000 to 5000 feet.

Huanaca hydroctylea (Bentham).—With the former plant; also northerly to Bogong High Plains; on wet, marshy upland flats; from 4000 to 6300 feet.

Apium prostratum (Labillardière).—In crevices of felsitic rocks at Day's Creek, near Omeo, at about 2000 feet elevation.

Seseli Harveyanum (F. v. M.).—This somewhat aromatic herb is common on the moist, grassy upland flats near Mount Cope, and on the Bogong High Plains, at elevations of 5000 to 6000 feet.

Aciphylla glacialis (F. v. M.).—On the Bogong High Plains; also on the basaltic plateaux at Mount Hotham, and on the slopes of Mount Cope, at about 6000 feet elevations.

SYNPETALEÆ PERIGYNÆ.

Santalaceæ (R. Brown).

Thesium Australe (R. Brown).—On the undulating ridges between Lake Omeo and the Mitta Mitta River; on argillaceous schist formation; at elevations from 2600 to 3000 feet.

Choretrum lateriflorum (R. Brown).—On ranges west of the Mitta Mitta, toward Mount Wills; argillaceous schist formation; at about 3000 feet elevation, and on the heads of Benambra Creek toward the Limestone Creek watershed, at about 4000 feet elevation.

Exocarpos cupressiformis (Labillardière).—The "turndun" of the Gippsland blacks is made from the wood of this species.—See pt. 1, p. 15.

Proteaceæ (A. L. de Jussieu).

Persoonia Chamæpeuce (Lhotsky).—Abundant on the undulating metamorphic schistose ranges of the western watershed of the Livingstone Creek, near Omeo; ascending to about 4000 feet.

Orites lancifolia (F. v. M.).—A handsome shrub, restricted to the rocky summits of the Great Dividing Range, and of the high lateral ranges, such as Mount Hotham, Mount Cope, Mount Latrobe (Bogong); in Silurian formation.

Grevillea ramosissima (Meissner).—At the junction of Livingstone Creek and Mitta Mitta; ascending on the granitic area of the Big River to about 3000 feet elevations.

Hakea eriantha (R. Brown).—On the lower levels of the Mitta Mitta source-basin, principally on gneissic schist and in the Silurian formation; ascends to about 3000 feet.

Caprifoliaceæ (Adanson).

Sambucus Gaudichaudiana (De Candolle).—This native elder is common on moist, rocky situations on the Dividing Range, near the heads of the Victoria River, at from 3000 to 5000 feet.

Compositæ (Vaillant).

Brachycome diversifolia (Fischer and Meyer).—Common all over the hills near Omeo, ascending to about 4000 feet.

Brachycome decipiens (J. Hooker).—Very common all over the area, flowering during early summer, ascending to about 5000 feet.

Brachycome augustifolia (Cunningham).—Abundant on the pasture land toward Omeo Plains; from 2400 to 3000 feet elevations; generally on alluvial areas.

Calotis scabiosifolia (Sonder and Mueller)—On the ranges east and west from Omeo and on the Victoria and Omeo Plains this species is prevalent; at elevations of 2000 to 3000 feet; proving troublesome to sheep-farmers owing to awns of the pappus getting entangled in the wool of the sheep.

Aster alpicola (F. v. M.)—On the higher ranges at the sources of Cobungra and Bundara Rivers, near Mount Cope; from 4000 to 6000 feet elevations; in Silurian and metamorphic-schist areas, and on Livingstone Creek, Omeo.

Aster stellulatus (Labillardière)—At the heads of Benambra and Livingstone Creeks, in palæozoic soils, ascending to about 5000 feet.

Aster florulentus (F. v. M.)—On the ranges west from Omeo and on the upland flats at Benambra Creek.

Aster celmisia (F. v. M.)—Near Mount Hotham at about 6000 feet elevation; on Silurian formation, and on the Bogong High Plains, in basaltic areas from 5000 to 6000 feet. This species is very abundant and gregarious, sometimes almost to the exclusion of every other plant.

Gnaphalium Japonicum (Thunberg)—On the slopes of Mount Cope, Mount Wells, Mount Latrobe (Bogong); at elevations of 4000 to 6000 feet; in granitic and Silurian formation.

Leontopodium catipes (F. v. M.)—On the summit of Mount Hotham, and on high peaks near it; at about 6000 feet elevation; in Silurian formation.

Podolepis longipedata (Cunningham).—Common on the grassy valleys at eastern watershed of the Livingstone Creek and the Mitta Mitta River; in mica-schist formation; ascends to about 3000 feet elevations.

Podolepis acuminata (R. Brown).—Abundant on grass land around Omeo; ascends to about 5000 feet along the upper sources of the Victoria, Cobungra, and Big Rivers; on mica schist, in granitic and Silurian formation.

Helichrysum rosmarinifolium (Lessing).—On the Livingstone Creek and Mitta Mitta River, and many of their tributaries; ascends to about 5000 feet, but nowhere gregariously, nor restricted to any formation.

Craspedia Richea (Cassini).—Common on the ranges near Omeo and on the Victoria River up to about 5000 feet; also on Flourbag and Precipice Plains.

Abrotanella nivigena (F. v. M.)—On the eastern slopes of the Bogong Plains, from 4000 to 6000 feet; in Silurian and metamorphic areas.

Senecio Georgianus (De Candolle).—On the ranges near Omeo, and on the Mitta Mitta River; in Silurian and metamorphic areas, on moist, shaded sidelings; ascends to about 4000 feet.

Cymbonotus Lawsonianus (Gaudichaud).—Very abundant all over the area, but most prolific on Silurian soils in shaded sidelings; ascends to about 6000 feet.

Erechtites hispidula (De Candolle).—On the rich alluvium at Omeo Plains, at about 2600 feet elevations.

Centaurea Australis (Bentham).—In similar localities with the foregoing, and on the low hills near Omeo Plains; ascends to 3500 feet.

Microseris Forsteri (J. Hooker).—Common along Livingstone Creek and at the Omeo Plains; ascends to about 6000 feet; on the upper courses of Victoria and Cobungra Rivers.

Campanulaceæ (A. L. de Jussieu).

Lobelia simplicicaulis (R. Brown).—On the granitic detritus near the heads of Livingstone Creek, at about 3500 feet elevation.

Isotoma fluviatilis (F. v. M.).—Common on the Morass Creek flats, near the Omeo Plains; in Silurian formation, growing in patches gregariously on the alluvial flats up to elevations of about 3000 feet.

Goodeniaceæ (R. Brown).

Goodenia hederacea, var. Cordifolia (Smith).—On the quartz porphyry slopes of M'Farlane's Lookout, near Omeo, at about 3000 feet elevation. Baron von Mueller is inclined to restore this to specific rank.

Velleya montana (J. Hooker).—Common on the open grass land near the Omeo Plains and Mount Leinster, in metamorphic-schist and porphyritic-granite areas; from 3000 to 4000 feet elevations.

SYNPETALEÆ HYPOGYNÆ.

GENTIANEÆ (Necker).

Limnanthemum crenatum (F. v. M.).—In the Morass Creek, near Omeo Plains, this handsome species is abundant; the fringed crest of the lobes of the corolla distinguish it from the following species.

Limnanthemum geminatum (Grisebach).—Also on Morass Creek, in similar situations.

CONVOLVULACEÆ (A. L. de Jussieu).

Convolvulus erubescens (Sims).—Common on the ranges near Omeo, between 2000 and 3000 feet elevation.

Convolvulus sepium (Linné).—Abundant on reeds in Morass Creek, near Omeo; not ascending higher than 3000 feet within the area.

Dichondra repens (R. and G. Forster).—Very common on mica-schist formation near Omeo, and near the margins of the western affluents of the Mitta Mitta on gneissic schistose areas; ascends to 4000 feet.

SOLANACEÆ (Haller).

Solanum aviculare (G. Forster).—On the alluvium near the junction of Livingstone Creek and the Mitta Mitta River, and on the tertiary gravels of the latter stream at lower levels.

Solanum vescum (F. v. M.).—Common on the moist heads of gullies south of the Dividing Range; thence to the littoral regions.

SCROPHULARINÆ (Mirbel).

Veronica nivea (Lindley).—At the sources of the Big River, near Mount Latrobe (Bogong), and on adjoining highlands. This species is seen principally on granitic areas from 5000 to 6300 feet elevations.

Euphrasia Antarctica (Bentham).—At the Bogong High Plains, on the basaltic plateaux, at about 6000 feet elevations.

LENTIBULARINÆ (L. C. Richard).

Utricularia flexuosa (Vahl).—Sparsely distributed on damp, grassy flats near Omeo Lake, at about 2600 feet elevation.

Utricularia dichotoma (Labillardière).—Common on moist slopes at the sources of springs, near Bogong High Plains, in Silurian and basaltic areas, at about 6000 feet elevation.

BIGNONIACEÆ (Ventenat).

Tecoma australis (R. Brown).—This handsome climber, so prolific in the littoral regions at the entrance to the Gippsland Lakes, ascends to elevations of about 3000 feet in this source-basin from the lower levels; generally in thickly wooded gullies.

ASPERIFOLIÆ (Haller).

Myosotis australis (R. Brown).—Common in similar localities with the following.

Myosotis sauvcolens (Poiret).—Ascends to about 5000 feet elevations, towards the Bogong High Plains, along the western affluents of the Mitta Mitta.—See pt. 1, p. 21.

LABIATEÆ (Adanson).

Mentha laxiflora (Bentham).—On the Livingstone Creek, near Omeo, in the mica-schist formation, at elevations of 2000 to 3000 feet.

Scutellaria humilis (R. Brown).—Sparsely distributed on the flats toward the Livingstone Creek sources, from 3000 to 4000 feet.

Prostanthera lasiantha (Labillardière).—See pt. 1, p. 21.

Prostanthera rotundifolia (R. Brown).—See pt. 1, p. 21.

Prostanthera cuneata (Bentham).—This erect or dicumbent species is restricted to the higher elevations, on rocky situations, occurring toward Mount Latrobe, at about 6000 feet elevations; and on the Cobboras Mountains, in granitic and porphyritic areas.

Westringia senifolia (F. v. M.).—On the alluvium at the junction of the Livingstone Creek and Mitta Mitta; an erect, bushy shrub, 5 feet high.

VERBENACEÆ (Adanson).

Verbena officinalis (Linné).—Not common within the Mitta Mitta source-basin (there confined to the flats along the Livingstone Creek); on the Tambo River more abundant.

EPACRIDEÆ (R. Brown).

Styphelia collina (Labillardière).—Common on the ridges dividing the western affluents of the Mitta Mitta, particularly in granitic areas; ascends to about 5000 feet.

Styphelia Macræi (F. v. M.)—Along the margins of the Mitta Mitta River and Livingstone Creek; ascends to about 5000 feet on the tributaries of the former. At the lower elevations this species attains a height of 10 feet; at higher places it becomes dwarfed, the branches get more densely pubescent, and the leaves are then less petiolated.

Styphelia ericoides (Smith).—On the upland flats at heads of the Livingstone Creek this species is very gregarious, forming a low, diffuse, heathy shrub; while on the porphyritic areas near Omeo Plains, from 3000 to 4000 feet elevations, it frequently attains a height of 3 feet, forming an erect, although bushy, shrub.

Styphelia juniperina (Sprengel).—This pretty shrub is most abundant on the Dividing Range at the head of Livingstone Creek; in Silurian formation, at about 4000 feet elevations, and is descending into the Livingstone Creek valley, in mica-schist formation, to 2000 feet.

Brachyloma daphnoides (Bentham).—Common on the northern stony slopes of Mount Livingstone, particularly in the neighbourhood of the auriferous belts of metamorphic schist, Dry Gully, Omeo, at elevations from 2000 to 4000 feet.

Trochocarpa pumila (F. v. M.).—On the granitic ridges at the junction of Cobungra and Big Rivers; at elevations of 3000 to 5000 feet.

Epacris petrophila (J. Hooker).—This low shrub is only met with at the higher elevations, not descending below 3000 feet. It is common on the upper sources of the Mitta Mitta, toward Mount Latrobe and the Bogong High Plains, at about 5000 feet elevations.

Epacris paludosa (R. Brown).—In similar localities with E. petrophila, but descending to 2000 feet elevations, as on the granitic area near the junction of the Big and Cobungra Rivers.

Epacris heteronema (Labillardière).—Along grassy gullies at the sources of the Cobungra and Big Rivers; in granitic, metamorphic, and Silurian areas; ascends to about 5000 feet, but becomes dwarfed and stunted at the higher elevations.

Richea Gunnii (J. Hooker).—Common on beds of spagnum on the Paw Paw and Bogong High Plains; in basaltic areas, from 4000 to 6000 feet height.

APETALEÆ GYMNOSPERMEÆ.

CONIFERÆ (Haller).

Nageia alpina (F. v. M.).—This is the only representative of the Coniferæ to be met with in this source-basin, and it appears to be restricted to the rocky alpine summits of the highest peaks, as Mount Wills, Mount Cope, and Mount Latrobe; in granitic and metamorphic schistose areas, of 5000 to 6500 feet. It extends easterly to the porphyritic summits of the Cobboras at about 6000 feet.

MONOCOTYLEDONEÆ.

CALYCEÆ PERIGYNÆ.

ORCHIDEÆ (Haller).

Dipodium punctatum (R. Brown).—This beautiful, leafless orchid is sparsely distributed over the dry, stony ridges within this area, being more abundant on the crests of the Silurian ridges on the littoral slopes of the Wentworth River, in the argillaceo-mica schist area, west of Lake Omeo, and on the Silurian ranges west from the Mitta Mitta River, toward Mount Wills; at elevations of 2000 to 4000 feet.

Spiranthes Australis (Lindley).—Abundant on the rich grass land at Mount Leinster Creek; on alluvial flats overlying granite-porphyry formation, at elevations of 3000 to 4000 feet.

Thelymitra aristata (Lindley).—Common on the open pasture lands on Livingstone Creek, at elevations of about 2500 feet, in metamorphic-schist formation; ascends to fully 4000 feet.

Diuris maculata (Smith).—Very common along the Livingstone Creek, Cobungra, Victoria, Bundara, and Big River valleys; on grass land; up to 4000 feet.

Diuris pedunculata (R. Brown).—Abundant along with the preceding species, in similar localities, and ascending to 5000 feet.

Prasophyllum patens (R. Brown).—On undulating ridges near Omeo and the Victoria Plains; at elevations of 2000 to 4000 feet; on mica-schist and gneissose-rock formations.

Pterostylis curta (R. Brown).—In the Livingstone Creek valley, at elevations of 3000 feet, and lower, it is frequently to be met with, particularly on rich grass land.

Caladenia Patersoni (R. Brown).—This very variable species is only sparsely distributed along Livingstone Creek and at Omeo on plains and grass land; it ascends to 4000 feet.

Glossodia major (R. Brown).—Common on pasture lands on the Victoria, Cobungra, and Big River valleys; also, on Livingstone Creek, at elevations of 2000 to 4000 feet.

Amaryllideæ (J. de St. Hilaire).

Hypoxis hygrometrica (Labillardière).—On the damp, rich flats of creeks flowing into the Livingstone Creek, in metamorphic-schist formation. It ascends to the higher plateaux, Paw Paw and Precipice Plains, at head of Victoria and Cobungra Rivers, in basaltic formation, at elevations of 4000 and 5000 feet.

CALYCEÆ HYPOGYNÆ.

Liliaceæ (Haller).

Drymophila cyanocarpa (R. Brown).—Rare in this source-basin; on the crest of the Dividing Range, near the head of the Livingstone Creek, at about 4000 feet, in Silurian formation; more abundantly it occurs on ranges near Grant, in Mitchell River source-basin.

Dianella revoluta (R. Brown).—Common on the dry, humid slopes of Mount Livingstone, near Omeo; at an elevation of about 3000 feet, in gneissic and mica-schist formation; also, on the Dividing Range, near the heads of the Victoria River, at about 4000 feet.

Wurmbea dioica (F. v. M.).—This pretty little species is seen very abundantly during early spring on the pasture lands around Omeo and at Omeo Plains; in fact, everywhere on moist flats, up to 4000 feet.

Bulbine bulbosa (Haworth).—This succulent annual is prolific on the grassy ridges near Omeo, at elevations of 2000 to 3000 feet.

Thysanotus tuberosus (R. Brown).—This handsome species is very abundant on the Mount Leinster Creek, near the Omeo Plains, on granite-porphyry formation, at an elevation of about 3000 feet; it is also to be met with on the slopes of Day's Hill, near Omeo, at about 3500 feet, on intrusive quartz-porphyry formation.

Cæsia vittata (R. Brown).—On rolling pasture-hills of the eastern watershed of the Livingstone Creek. This species is prevalent at elevations of 2000 to 3000 feet, in metamorphic-schist formation.

Tricoryne elatior (R. Brown).—On grassy edges of small streams flowing into Livingstone Creek, at elevations of 2000 feet; more abundant on the limestone area of Bindi, south of the Dividing Range.

Stypandra glauca (R. Brown).—On grassy flats along the Livingstone Creek (especially in tufts of Poa cæspitosa) this species is plentiful; it ascends to 4000 feet.

Xerotes longifolia (R. Brown).—On rocky slopes of the eastern watershed of the Livingstone Creek, on mica-schist formation, at elevations of about 3000 feet.

Xanthorrhœa australis (Smith).—Not frequent in this source-basin; confined to the dry, stony slopes of the Dividing Range, near Omeo, on argillaceo-mica-schist formation, at elevations of about 3000 feet; more abundant on granitic areas south of the Dividing Range.

Typhaceæ (A. L. de Jussieu).

Sparganium augustifolium (R. Brown).—Only known at present from Lake Omeo and Morass Creeks; at an altitude of about 3000 feet above the sea-level.

Fluviales (Ventenat).

Potamogeton natans (Linné).—This species was seen by me only in the waterholes of Wilson's Creek (eastern affluent of Livingstone's Creek), at an altitude of about 2200 feet; it is probable, however, that it is yet to be met with at higher elevations within this source-basin.

Junceæ (R. Brown).

Luzula campestris (De Candolle).—Abundant almost all over the area, up to 5000 feet, in damp situations.

Juncus bufonius (Linné).—Along the banks of watercourses of the Livingstone Creek watershed, up to 4000 feet; particularly prolific on the soft mica-schistose formation near Omeo.

Juncus communis (E. Meyer).—Abundant on wet flats near Omeo, on metamorphic-schist formation, from 2000 to 3000 feet, and ascending to much greater elevations.

Juncus prismatocarpus (R. Brown).—Similar in its stations to Juncus bufonius.

Restiaceæ (R. Brown).

Restio australis (R. Brown).—On marshy alluvium at the head of Livingstone Creek, from 3000 to 4000 feet elevation, and along the Dividing Range, from Mount Tambo to Mount Cobboras and Mount Pilot, at about 6000 feet elevation; on marshy flats.

Calostrophus lateriflorus (F. v. M.).—On the source-runnels of the Cobungra and Bundara Rivers, intersecting Bogong High Plains; in basaltic areas. This species is abundant, and generally found growing on beds of spagnum, sometimes attaining a height of 3 feet.

ACALYCEÆ HYPOGYNEÆ.

Cyperaceæ (Haller).

Kyllinga intermedia (R. Brown).—On the alluvial flats at the junction of the Livingstone Creek and the Mitta River, at about 1600 feet; not seen at higher elevations. It ascends to this station from the Murray River at lower levels.

Cyperus Eragrostis (Vahl).—On the granitic area at the junction of the Cobungra and Big Rivers, at about 2200 feet, and on the Mitta Mitta below its junction with the Livingstone Creek; on metamorphic-schist formation, at an altitude of 1000 to 1600 feet.

Cyperus lucidus (R. Brown).—Common on shaded hill-sides, at the sources of springs, on the Livingstone Creek; up to 4000 feet. On southern side of Mount Livingstone, at elevations of 3000 feet, it occurs in its greatest luxuriance, the stems frequently attaining a height of 5 feet.

Scripus polystachyus (F. v. M.).—On Morass Creek, near Lake Omeo, and on the Mitta Mitta River, at elevations from 1000 to 3000 feet.

Schœnus Brownii (J. Hooker).—On damp soils near Omeo.

Lepidosperma concavum (R. Brown).—Common on the rocky, exposed northern slopes of Mount Livingstone, near Omeo, at elevations of about 3000 feet, on mica-schist formation, and on the northern slopes of the Dividing Range, east from Omeo, in argillaceo-schist formation, at between 2000 and 4000 feet elevation.

Lepidosperma lineare (R. Brown).—In similar localities to L. concavum, and northerly toward Mount Leinster, on granitic-porphyry formation, at elevations from 3000 to 4000 feet.

Uncinia tenella (R. Brown).—In shaded gullies among fern-trees on the Dividing Range, east from Omeo, in argillaceo-mica-schist formation, at elevations from 3000 to 4000 feet.

Carex acicularis (Boott).—On the Paw Paw tableland, in basaltic formation, at about 5000 feet, and on the heads of the Cobungra River, near Mount William, in argillaceo-schist formation, at elevations of about 6000 feet. This small species is abundant; it does not appear to descend within this source-basin below 4000 feet.

Carex inversa (R. Brown).—Common along the sandy alluvial flats of Livingstone Creek; at elevations of 2000 to 4000 feet.

Carex vulgaris (Fries).—On swampy flats and marshes along Wilson's Creek, near Omeo, ascending the Dividing Range to 4000 feet.

Carex acuta (Linné).—On the heads of the Cobungra, Victoria, and Big Rivers, at elevations from 3000 to 5000 feet.

Carex Buxbaumii (Wahlenberg).—On the upland flats near Mount Hotham and on the Bogong High Plains, at elevations from 3000 to 5000 feet, and on the Livingstone Creek and Omeo Plains, at about 3000 feet elevation. It appears to flourish best on rich basaltic soils in marshy localities. Identified with numerous other alpine plants already by Baron von Mueller, 1853-55.

Carex breviculmis (R. Brown).—On the eastern watershed of the Livingstone Creek, near Omeo, and on the Victoria Plains, at elevations from 2000 to 4000 feet, in mica-schist and metamorphic-granite areas.

Carex longifolia (R. Brown).—Common on marshy upland flats at Wilson's Creek, near Omeo, in metamorphic schistose formation, and along the flanks of Mount Livingstone, at elevations of about 3000 feet, and at higher elevations in the Australian Alps.

Carex Pseudo-Cyperus (Linné).—In similar localities with C. longifolia, and even more widely distributed in marshy localities at lower elevations; ascends to 4000 feet.

GRAMINEÆ (Haller).

Panicum melananthum (F. v. M.).—On the eastern margin of the Omeo Plains, near Mount Sisters, at elevations from 2000 to 3000 feet, and thence easterly in the Tambo River watershed to Bindi, at 1600 feet, in metamorphic, granite, and limestone (Middle Devonian) areas.

Hemarthria compressa (R. Brown).—Along margins of races on the Livingstone Creek watershed, near Omeo, on mica schists, at elevations from 2000 to 3000 feet.

Andropogon refractus (R. Brown).—On the Hinnomunjie Flats, at the junction of the Livingstone Creek and Mitta Mitta River, at about 1600 feet elevation. It appears to be emigrating to sub-alpine heights from the lower Mitta Mitta.

Anthisteria ciliata filices (Linné).—This, the well-known kangaroo grass, is, perhaps, the most abundant of the Gramineæ throughout the area, ascending from the undulating metamorphic ranges near Omeo to the higher basaltic plateaux at Paw Paw and Precipice Plains, and to the still higher Bogong High Plains, at about 6000 feet elevation. Near Omeo the stems are frequently seen to attain a height of 4 feet, and on shaded hillsides even 5 feet.

Hierochloe redolens (R. Brown).—A common species on the undulating ranges on eastern watershed of Livingstone Creek and at the Victoria Plains, and on the southern granitic slopes of mountains near the junction of Big River and Cobungra; it ascends to 5000 feet; that found near Omeo belongs to the variety called Submutica.

Stipa scabra (Lindley).—On the grassy slopes of the Dividing Range, on the eastern watershed of the Livingstone Creek, at Omeo Plains, and on the Victoria River; ascends to 4000 feet.

Dichelachne crinita (J. Hooker).—On shaded, grassy gullies, near Omeo, at elevations from 2000 to 3000 feet; abundant.

Agrostis Solandri (F. v. M.).—Very common within the area on the metamorphic-schist and Silurian formations, up to 4000 feet. This forms a good winter grass.

Echinopogon ovatus (Palizot).—Common on the Livingstone Creek, near Omeo, at about 2000 feet, and on the Victoria Plains and Omeo Plains, at 3000 feet elevation; ascends to 5000 feet.

Aira cæspitosa (Linné).—On the Livingstone Creek flats, very abundant, at elevations of about 2000 feet; ascends to 4000 feet. After bush fires this tussocky grass forms good forage.

Trisetum subspicatum (Palizot).—This alpine species is common on the upper affluents of the Mitta Mitta, on the grassy slopes of the higher plateaux at the heads of the Victoria, Cobungra, and Big Rivers, and on the moist flats at head of the Livingstone Creek; ascends to 6000 feet.

Danthonia penicillata (F. v. M.).—A common species on the slopes of Mount Cope, at 6000 feet; at the head of Cobungra River; on the undulatory rises of the Bogong High Plains, up to 6000 feet; and at the rocky ridges, near Mount Bogong, up to 6500 feet. Most prolific on the basaltic areas, but not restricted to this formation.

Poa cæspitosa (G. Forster).—This densely tufted and variable species is common all over the area on upland dry flats; ascends to 5000 feet. The stems attain a height of 5 feet in favourable localities, especially on the western watershed of the Livingstone Creek; at 2300 feet elevation.

Poa dives (F. v. M.).—On the southern slopes of shaded hill-sides this erect grass attains a height of 12 feet. It is seen on the southern side of Mount Livingstone, and on the Big River, at elevations of 2000 to 5000 feet; also on the Dividing Range, near Tongio Gap, at 4000 feet. It appears to be most prolific on Silurian areas. The whole plant is succulent and tender, and if cultivated should form an excellent fodder grass.

Festuca bromoides (Linné).—Common on the ranges near Omeo at from 2000 to 3000 feet; at Omeo Plains, and generally on open situations in the area, up to 4000 feet; on dry, gneissic areas.

Festuca Hookeriana (F. v. M.).—On the Bundara River, at about 3000 feet elevation; on the Benambra Creek uplands, to 4000 feet; thence easterly to the Cobboras Mountains; abundant on porphyritic areas. Forms at these stations one of the best pasture grasses.

Agropyron velutinum (Nees).—At the head of the Cobungra River, near Mount Hotham, on Silurian areas, from 4000 to 6000 feet, and on the Dividing Range, east of Omeo, at about 4000 feet.

Nearly the whole of the plants here enumerated were named by Baron von Mueller from specimens transmitted for this purpose to his office.

Art. IV.—*Shingle on the East Coasts of New Zealand.*

By W. W. Culcheth, M. Inst. C.E., F.R. Met. Soc.

[Read 8th May, 1884.]

1. The following has been written from observations lately made by the author in New Zealand. The conditions attending the shifting of the materials which form the coast in many places are of great interest to the engineer who has to design protective works or harbours in such localities. This paper deals more particularly with travelling shingle, a subject that has given rise to much controversy. So long ago as 1853 a paper on the Chesil Bank on the south coast of England was read before the Institution of Civil Engineers by Mr. (now Sir) John Coode, whose name is well known in these colonies. The late Astronomer Royal, Sir George Airy, took part in the discussion on that paper, differing in opinion on certain points from Sir John Coode. This discussion was renewed at intervals, and so lately as 1875 an agreement on the points of difference had not been arrived at. The opinion of those of the leading engineers who were not prepared to support one side or the other in these discussions, was that more information was required from other localities, and that it was unsafe to generalise from the results observed at the Chesil Bank.

2. In this paper a few facts only will be stated, with some deductions from them, the object being to direct attention to the subject in this part of the world, in order that more information may be collected and further light thrown on the movements of shingle under varied conditions. Sir J. Coode remarked in his paper of 1853:—"There are few subjects of greater professional interest than the accumulation and travel of shingle, since the very existence of many harbours depends, in a great degree, upon a correct understanding and judicious application of the laws which govern its movement; and without a knowledge of these it is impossible to devise such measures as may with confidence be adopted, either to assist its progress, direct its course, or to remove accumulations that may have taken place."* Shingle

* See *Proceedings of the Institution of Civil Engineers*, vol. xii., p. 520.

is the chief subject of this paper; but the action of the waves on sand cannot be wholly neglected, as the difference is chiefly one of degree.

I.—Description of the two Beaches Visited.

3. The author visited what is known as the Ninety-mile Beach, on the east coast of the South, or, as it used to be called, the Middle, Island, and the beach near Napier, in Hawke's Bay, on the east coast of the North Island.

4. The Ninety-mile Beach extends from Banks' Peninsula in a south-west direction to Timaru, but the same beach really extends some 50 miles further down the coast in a southerly direction to Oamaru. There is an uninterrupted shingle beach over 130 miles in length. The principal source of supply of this shingle is the River Waitaki, or, as it is called on the Admiralty chart, the Waitangi, which is about 14 miles north of Oamaru. "Cliffs from 30 to 40 feet high" are marked on each side of the mouth of this river. Some of the shingle is said to come from these cliffs. The shingle on the beach opposite Oamaru is evidently driven there when the wind is north of east. South-easterly weather would formerly tend to denude the beach, but since a breakwater has been constructed at that place shingle has been collecting opposite the town. It is said that the accumulation near the mole on the north side of the new harbour has ceased; but this may be only temporary. The same agency which caused the present accumulation is still at work. North-easterly weather must continue to drive shingle down the coast from the River Waitaki, and unless the mole causes the shingle to be deposited at a point sufficiently distant to allow of its being carried back during south-easterly weather the accumulation must go on, though it may be but slowly.

5. South-easterly weather prevails on this coast, and as the beach between Oamaru and the River Waitaki is supplied chiefly from that river, which is to the northward, this beach is probably at times denuded, the cliffs being then cut away. The beach between the river and Timaru is probably less subject to change, owing to the chief supply of shingle being at the end from which the prevailing seas come.

6. South-west of Timaru, at the end of the town, is Patiti Point, where there is a low cliff with a shingle beach n front. It is at first difficult to account for the beach

existing at this point, and for the cliff, which is composed simply of earth, not being cut away; but there is a sunken reef running some distance out to sea in front, which evidently protects the cliff in bad weather. The beach can take care of itself, and can also protect the cliff at ordinary times. North of this is another reef, but of less extent; it shelters the harbour somewhat from heavy south-east seas.

7. At Timaru a breakwater is being constructed with a view of making the harbour more safe than hitherto. This work has given rise to much controversy from the fact of its being in the middle of a beach of travelling shingle. Sir J. Coode gave a design for a breakwater and harbour detached from the shore to allow of the shingle travel going on uninterruptedly. The plan was not locally considered satisfactory, and a solid breakwater running out from the shore was resolved upon instead. This work is now going on. At first it was proposed to construct a length of some 400 or 500 feet only; but it being found that the shingle was likely to get round the end of the work, its length was increased, first to something less than 1000 feet, the author believes, and then to 1400 feet. The latter length has now been constructed, and the result is, in Timaru itself, generally considered very satisfactory, the shingle having been driven back by the waves reflected from the breakwater. After the work had been carried out to a length of something over 700 feet, the shore line at high-water level began to recede, and continued to do so for a year or more. It has since advanced a little, but this is probably of no great importance, as changes must be expected, according to the weather. Occasionally, during a gale, the shingle is thrown up on to the top of the breakwater, which is 6 feet above high-water level. The shingle would be carried over the work were it not cleared away by manual labour.

8. A far more serious point is that an accumulation is taking place a few hundred yards away from the breakwater, where the reflected waves cease to have any effect. The Government engineers and others who were opposed to the work from the first, expressed the opinion that in time shingle would swamp the work, and render the harbour useless. Various periods of time, some extending as far ahead as twenty years, were allowed before this should take place. The people of Timaru, however, laugh at these opinions, and consider the work will be a success. It is not denied that shingle continues to come up the coast, but the breakwater

having kept back the shingle some four years or more, it is hoped that it will do so always. They do not ask what becomes of the shingle, or what will become of it in course of time. The action at Napier, which will be mentioned presently, may prove instructive in connection with this matter. (See pars. 13 and 14.)

9. Another result of the construction of the breakwater at Timaru may be mentioned to show that travelling shingle cannot always be obstructed without some evil following. When the shingle was stopped by the breakwater the beach in the bay in front of Timaru was entirely denuded, and a serious erosion of the banks commenced. Very heavy expenditure has been incurred in throwing down large blocks of stone along the shore to protect the railway from being destroyed. It was at one time even proposed that the breakwater should be cut through to allow of shingle passing as before. This was not done. The denuding of this beach occurred before the breakwater had been carried out far enough to shelter the beach from the action of south-easterly seas, although it was sufficient to keep back shingle coming up the coast from the south. The bay is now more sheltered, and will become more and more so as the breakwater is carried further out. The northern part of the bay is, however, exposed to seas from the east and north-east, which must carry shingle down the coast, contrary to the general direction. There is shingle less than $1\frac{1}{2}$ miles up the coast, in front of the Waitarakao lagoon. Some of the shingle so carried down the coast is likely to come under the shelter of the breakwater, so that it will not be carried up the coast again by south-easterly seas. Shingle will then begin once more to accumulate in front of the town as at Oamaru. This result may already have commenced, although possibly there is too little shingle to have attracted notice as yet.

10. Between Timaru and Banks' Peninsula there are several rivers, against four of which it is noted on the chart, "Mouth always open;" the others are probably closed except during freshets. The author does not know whether these rivers bring down further supplies of shingle or not; probably they do, for the whole of this part of the country is said to have a substratum of shingle. The beach is, however, continuous up to Banks' Peninsula. The last twelve or thirteen miles, in front of the Waihora Lake (also called Lake Ellesmere), is really a broad neck of shingle, in some places nearly a mile in width. This encloses a large sheet of water,

marked "Very shallow and brackish." The bed of this lake, and the bank in front of it, represent the shingle accumulation since the present beach began to be formed. The author was informed that a series of ridges are to be seen where probably the beach has been in successive periods, and at the extreme end the shingle has been thrown up against a cliff to a height of 30 feet above sea-level.

11. The advance of shingle beyond this point is prevented by the trend of the coast-line changing suddenly to east-south-east, so that shingle could not be carried on unless by a sea coming from the west-south-west, or a more westerly point, which would be directly along the shore or off-shore. Waves of any size could not therefore be formed; and should any small quantity of shingle be carried forward by these waves, it would be carried back by a change to the south-east, the prevailing direction.

12. The shingle beach in Hawke's Bay extends from eleven miles south of Napier to ten miles north of that place, where a projecting cliff arrests the steady advance of the shingle. Beyond this cliff is a beach, partly of sand and partly of shingle, for a further length of over thirty miles, the general direction being north-easterly. The chief source of supply of the shingle is the River Tuki Tuki; and the prevailing direction of the seas on this coast, as on the Ninety-mile Beach, is south-easterly, but north-east seas at times cause great changes in the shingle. The general movement of the shingle, from the mouth of the River Tuki Tuki as far as Napier, is due to seas coming from any direction south of east. For some distance south of Napier there is merely a narrow belt of shingle, forming the only connection between the mainland and the town, the high part of which was formerly known as Scinde Island. It is, indeed, asserted that Captain Cook sailed round this island. If this be correct, the shingle accumulated in the neighbourhood is but of recent growth. Beyond the Bluff, at Napier, the south-east seas have very little effect, and the chief movement is due to seas coming north of east.* From the exposed position of the Bluff, the beach below it is liable to change very much. It would, doubtless, often be entirely denuded of shingle but for the protection afforded by large blocks of stone which have fallen into the sea from the cliff.

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* The difference, at times, between the direction of the wind and that of the waves must not be overlooked. (See App. *b*, p. 81.)

13. One mile and a quarter west of the Bluff is the entrance to the present harbour. To improve this, a few years ago, two moles or jetties were run out into the sea. As that on the east side of the entrance was being constructed the shingle, for a time, advanced with the work. At last "the work got ahead of the shingle, which gathered at a much slower rate; but although the high-water line did not advance, the shingle at low-water line was spreading further out." The waves reflected from the work drove back the shingle along the shore at the high-water line a distance, at first, of about 800 yards, which gradually was reduced to 500 yards. The shingle here accumulated for a year or more, when "a very heavy north-easterly sea set into the bay," and this "accumulation of shingle, &c. . . . . advanced right up to the mole within the space of two days."

14. Such was the end of this attempt to keep back the shingle. The mole projects a less distance out than the breakwater at Timaru does, but the result at Timaru must in the end be similar, though it may take a longer time. There is one other difference between the two cases. The mole at Napier is sheltered from south-east seas, though the swell is felt. The breakwater at Timaru is also sheltered from the full force of heavy south-east seas, but sufficient wave-action from that direction is felt to cause the shingle to advance. It is difficult at present to estimate the different results likely to ensue from this difference, but it is not likely to alter much the final result, unless, in the case of Timaru, the advance be more gradual than at Napier. It may be remarked that, in the same way as at Timaru, shingle is, in bad weather, thrown up on to the mole at Napier, the top of which is also 6 feet above high-water level. Not being cleared away, the shingle is washed completely over the mole.

15. After passing the entrance to the present Napier harbour there is now a large accumulation of shingle, which is mainly due to the shelter afforded by the western mole. After this there is a long spit of shingle, the trend of which gradually changes from north-west to north, enclosing a large lagoon, called the Ahuriri Lake. The spit joins the mainland four miles from Napier. Seven miles further on, after enclosing another small lagoon, the beach ends at the cliff before-mentioned. This cliff projects from the mainland for about a mile, in an east-south-east direction. As

this is almost at right angles to the beach, no waves of any size can be formed to carry the shingle along it. The advance of shingle beyond this point is probably due to the cutting-out action which takes place at times, the finer material being drawn under the water-line by certain waves. On this point more information is required.

16. The largest stones, or pebbles, which composed the shingle seen by the author in New Zealand seldom measured more than 6 inches by 4 or 5 inches by 3 inches. Several stones, measuring a third or so more each way, were seen near the mouth of the River Waitaki. The usual size of those on the beach was, however, much less than above stated; occasionally, near Napier, it was little more than that of coarse sand. These stones have, evidently, from their rounded appearance, before being thrown on to the beach, been subjected to the action of water in a former age, and are now found embedded in earth. They are chiefly derived from the rivers already mentioned, down which they are carried during freshets.

17. A further source of supply is in the mountains in which the Canterbury rivers have their source, where there are "long slopes from 500 to 1000 feet high, as regular as the slopes of a railway embankment, and formed entirely of clay-slates, broken up to the size of road metal; the stone lies at an exact angle of repose, and if a shovelful were taken from the foot the movement would extend to the top of the slope. . . . Even where the rocks are not actually broken up, they are so easily disintegrated that every small stream forms a large fan of shingle when it reaches the valley. During floods the streams cut deep gulches through these fans, carrying the shingle away into the main river." The inclination of the bed of the River Waitaki "is between 30 and 40 feet per mile, while that which the bed of a river of the same size would take if no new shingle were brought into it would not be greater than 3 or 4 feet per mile."* The cliffs along the coast, particularly on the South Island, are said also to furnish a large portion of the supply of shingle.

18. The banks of the rivers are very subject to erosion, and great changes frequently take place in the course of

* See New Zealand Parliamentary Paper, No. 2, of 1880, pp. 10, 11. Evidence of Mr. Carruthers, Engineer-in-Chief, relative to the Oamaru and Timaru Harbour Works.

some of the rivers. During floods, the material cut away from the banks is carried down stream, and a portion is deposited where the force of the current is diminished from any cause. The beds of the rivers above mentioned are strewn in places with stones and pebbles of all sizes. As the force of the stream is reduced and becomes insufficient to keep material in suspension, it is thrown down; and thus it is at the mouth of the rivers the largest deposit takes place. The stones and pebbles are there thrown in a large mass on the shore, almost, sometimes quite, blocking up the mouth, while the earth is carried away into the sea. Soundings show that much stone (described as gravel on the charts) is also carried into the sea; but a great deal of this is doubtless thrown up again on to the beach, as the author will endeavour to show later on. The material is mostly a bluish-grey stone, usually described as clay-slate.* The shape of the stones, or, more correctly, pebbles, may be described as flattened ovoids.

II.—Agency by which Shingle is Caused to Travel.

19. Material once deposited as above must, owing to its *vis inertiæ*, remain till some greater force than that of the current from which it was deposited comes into play. That deposited in the river bed may be removed by a succeeding flood; that near the mouth of the river may be removed by a greater flood than the first one; but the disturbance by floods of the material once deposited in the sea or on the seashore must be limited. The action of the sea itself must be looked to for any further movements of the material. In the sea two forces may be considered—(1) currents, which may be tidal or otherwise; and (2) waves. Currents along a coast, unless in exceptional localities, are usually of no great velocity, and, consequently, able to transport the finer materials only. The tidal flow into and out of an estuary, creek, or lagoon may be strong, and capable of moving large and heavy bodies, like a flood of similar strength in a river; but the action fails soon after the current enters the sea, in the same manner as the flood of a river then loses its force. With the exception of this tidal flow into and out of rivers

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* Most of the stones from both coasts show, when fractured, a silicious composition. Some stones, frequently found near Napier, are evidently from a sandstone formation.

and lagoons, the author does not know of any current of much strength on the coasts to which this paper more especially relates. The wave-action, then, is the chief agent concerned in the transport of the shingle along the Ninety-mile Beach, and near Napier.

20. The power of waves during a heavy sea is sometimes extraordinary. At the Plymouth Breakwater, blocks of stone weighing several tons each have been washed from the sea-slope over to the land side of the work. At Wick, a mass of concrete and stone, weighing nearly 1400 tons, was, in 1872, gradually slewed round by successive strokes of the waves until it was finally removed from its place and deposited inside the pier. During one storm, "two stones, of 8 and 10 tons in weight respectively, had been carried over the parapet and lodged on the roadway of the breakwater." During a heavy gale on the west coast of Scotland, in 1829, waves were observed to exert a force of nearly 3 tons per square foot. At the south-east end of the Chesil Bank pebbles have been thrown to a height of 42 feet above high-water level. Numerous other examples might be given, but these will be sufficient to show that a very moderate sea is likely to be sufficient to move pebbles of the size above given and weighing not more than 7 lbs. or so. Professor Rankine gives a table* showing that large shingle is moved by water having a velocity of 4 feet per second *close to the bed*, which would ordinarily be equivalent to a surface velocity of, say, 5 miles an hour. This velocity might, under favourable conditions, be generated by waves of one foot or so in height. Little is, however, known accurately of the actual power of waves to move stones of given sizes. The author has observed pebbles of about the above weight (say 7 lbs.) not to be moved by waves of 2 to 3 feet in height; but this might be partly due to a thin edge of the stone being exposed to the water. Again, stones which have resisted the force of several waves in succession may be suddenly removed by a wave apparently no larger than those immediately preceding it.

III.—Action of Waves on a Beach.

21. The *tendency* of wave-action is, when not otherwise expressed, referred to in the following remarks on this subject. The actual effect is that due to the resultant of the

* See *Civil Engineering*, 9th ed. (1873), p. 708.

several forces at work. The real difficulties of the subject lie in apportioning to the several forces at work their relative value, so as to obtain a proper resultant, and, more particularly, in ascertaining what force is required to move materials of a given size and weight, and where such materials will be deposited as the power of the water to retain them in suspension is destroyed.

(a.) How Shingle is caused to Travel along the Shore.

22. Waves before breaking, being waves of oscillation merely, have, in general, very little effect on the material forming the bed of the sea. After the waves have broken they become waves of translation. On a wave breaking on any shore, or on a wave which has broken at a distance reaching the shore, a large quantity of water is, as every-one may have seen, thrown forward and flows up the slope, gradually decreasing in velocity till it reaches a certain point, from which it flows back down the slope. The water falling from the crest of a wave, on breaking, stirs up some of the material forming the beach. This will take place to a considerable extent if the water fall directly on to the beach, but to a less extent if it fall on to a cushion of water of some thickness. In the former case, a portion of the material disturbed is carried up the slope by the force of the water, and probably some material is carried by a back current (or under-tow) down the slope under the water-line. In both cases the return wave also will carry some material, when not too large, down the slope with it.

23. If the waves come directly on-shore, the material is carried alternately up and down the slope in lines nearly at right angles to the shore-line, so that the position of the particles laterally is altered but little. If, however, the waves come obliquely on to the shore, the particles are carried up the slope obliquely, and, on being washed down again, are somewhat in advance of the position they first occupied, the advance corresponding with the motion of the waves along the shore. The more acute the angle, within certain limits (probably about 45°), at which the waves strike the shore, the greater the advance of the material at each movement.

(b.) Wave-action on a Beach under various conditions.

24. When a wave breaks on a shingle beach and carries stones up the slope, these stones will be gradually deposited as the velocity of the water decreases, the largest first and

the smallest where the force of the water is least. The return wave will increase in force as it descends the slope, and it will gradually remove larger and larger stones till its force be checked. The steeper the slope the more rapidly will the on-shore wave be destroyed, and the more rapidly will the return wave increase in force; and *vice versâ*. Whether the return wave can remove and carry down the slope as large stones as had been deposited by the on-shore wave, or not, will depend on the slope of the beach. On a flatter slope than usual, the return wave will not acquire sufficient force; but, on a slope steeper than ordinary, it will doubtless acquire the force. Under certain conditions, all the largest stones are deposited at the highest level; under certain other conditions, at the lowest level. It must be noted that the return wave flowing down a slope is not destroyed on meeting an on-shore wave. The two waves cross, and the return wave continues its course away from the shore, gradually becoming less and less.

25. It was remarked just now that a wave breaking on, or close to, the shore stirs up the material of the beach, and doubtless some material is also carried by a back current down the slope under the water-line. This is a very important point to consider; the more so, as it is difficult to observe clearly this action on the material of which the beach is composed. A floating body may be seen on the point of being thrown by the waves on to the beach, when it will be suddenly drawn under the surface of the water, and will in a short time reappear some distance off the shore. When a wave breaks, it is probable that the particles of water in the trough of the wave continue the backward (off-shore) motion they had immediately before the wave broke. If such be the case, each wave breaking *on* the shore, or so close to it for this backward motion to be felt on the beach, has a tendency to draw under the water-line some of the material disturbed, as well as to carry material up the slope, as above explained.

26. If an on-shore wave break at a distance from the shore, and on to a considerable cushion of water, the backward motion of the water in the trough of the wave is not likely to have any appreciable effect on the material disturbed from the beach. The water falling on to a cushion of water from the crest of a wave would, as before remarked, stir up the material of the beach more or less according to the thickness of the cushion and the size of the material. The chief horizontal movement likely to take place would be

due to the return waves flowing as an undercurrent down the slope. The material would therefore be carried seawards. The slope is here supposed to be fairly uniform from above the shore-line downwards; the case being, in fact, a beach, and not a shoal or bar on which waves break. The effect in the latter case would be different, there not being a return wave of a similar description.

27. The movement of the larger material down the slope is doubtless soon arrested. The flow from an incoming wave after breaking would cause most of it to be deposited at the point of meeting the return wave; or, on reaching the water-line, it would receive a check and be deposited; hence, large shingle is often not found below the water-line. Waves following at long intervals, or so as to allow the return waves full play, would allow large stones to be washed down to the water-line, or possibly a little below it. But waves following in rapid succession must check early the action of the return waves, and either prevent their taking up much material, or cause the deposition *above* the water-line of any large stones they may have moved. Small shingle and sand might be carried on, as the return wave would not, as before remarked, be destroyed. An incoming, or on-shore, wave passing over would, by causing an oscillatory motion, temporarily arrest the seaward motion, and might allow some of the material to be deposited, but the finer material would be carried on. Fine sand would probably be carried a long distance out. These results may be briefly stated as follows:—The coarser and heavier the material of the beach, the less it will be drawn below the water-line; the finer and lighter the material, the more readily it will be drawn below that line; the slope in each case being the same.

28. It would appear, then, from the foregoing remarks, that, theoretically, the shingle should be arranged in regular order on a beach, the largest stones at the water-line, or at the level where the force of the waves is greatest, that is, probably from a little above low-water level to a little above high-water level, and smaller stones higher up; the stones should also decrease very rapidly in size downwards under low-water level. The vertical cross section, or profile, of the shore tends to become convex above high-water level and concave below low-water level, and perhaps straight between the two levels. Practically, these results are not always arrived at, and when obtained they are seldom

lasting; the arrangement of the shingle on a beach is, as a rule, perpetually changing. Occasionally, a permanent arrangement may be met with, as, for instance, when a heavy sea, especially during a high spring tide, has thrown pebbles up to a position from which the ordinary waves may be unable to displace them.

(c.) *Action on the Bed of the Sea near the Shore.*

29. Water falling from the crest of a wave on to a cushion of water would, in stirring up the bed, cause some of the material to rise in the water. The deeper the water-cushion the greater the force necessary to disturb the bed, the material being the same. The particles, on approaching the surface, would be carried towards the shore by the waves (after breaking), or, in some cases, by the wind if blowing in that direction. The greater the force of the waves, as a rule, the coarser and heavier the material liable to disturbance. With a heavy sea and a gale blowing on shore, large stones might easily be transported from a considerable depth in the bed to the beach.

30. The greatest depth at which this action could take place is uncertain. It is often said that loose rubble is safe from disturbance at a depth of 15 feet; some say at any depth over 12 feet. The rubble foundation of the Alderney Breakwater was, however, disturbed at a depth of 20 feet below low-water level.* Much must depend on the size of the stones used for rubble. It is on record that "drift stones of large dimensions, measuring upwards of 30 cubic feet, or more than two tons in weight, have, during storms, been thrown upon the [Bell] Rock from deep water."† For shingle the above limits of depth are far too little. Sir John Coode remarked, after an examination of pebbles in the bed of the sea in front of the Chesil Bank:—"These facts demonstrate clearly that at a depth of 6 and 8 fathoms there must have been a considerable amount of motion during heavy gales."‡ The late Astronomer Royal concluded that in some places the stones on the beach "had been torn up by the violence of the surf from the bottom of the sea."§

31. The opinion of the late Astronomer Royal did not meet with general acceptance. It was controverted, as

* *Proceedings of the Institution of Civil Engineers*, vol. xxxvii., pp. 74 and 108.
† Ibid., vol. vii., p. 333. ‡ Ibid., vol. xii., p. 535. § Ibid., vol. xxiii. p. 228.

regards shingle, by Sir John Coode in particular, who admitted the disturbance by wave-action of shingle at depths of 6 and 8 fathoms, but denied that the material was thrown up on to the beach.* The author, without pretending to decide a point on which such authorities are at variance, will venture to suggest that the difference is chiefly one of degree, since there are numerous instances recorded of stones being thrown up from great depths. Sir John Coode, therefore, could not have intended to deny the action *in toto;* he evidently meant that it did not take place to any great extent. At great depths, unless there is a projecting rock or other obstruction to the waves, there is little more than an oscillatory motion of stones, the size of large shingle, caused by even the heaviest waves at the surface of the sea, such waves not being waves of translation so long as the depth of water exceeds the height of the waves. Although these waves might not have power to transport to a distance stones of the size alluded to, a current of moderate strength could do so when the stones had once commenced to move, or had been lifted from the bed by wave-action. Now and then the stones might be carried within the influence of waves of translation, and might then be thrown up on to a beach or elsewhere. In this way, the facts just mentioned can be understood, while, at the same time, the results, as dependent on wave-action, may be looked upon as exceptional.†

32. A belt of discoloured water may often be seen along the shore when nothing but shingle is to be seen on the beach. This may be due to fine material carried downwards by the return waves (flowing off-shore as an undercurrent), or to material stirred up from the bed of the sea by the on-shore waves. The apparent width of this belt is not necessarily the extent to which material is held in suspension, because that on the surface is frequently in motion towards the shore. The attention of the author was drawn to the fact of this belt of discoloured water being sometimes wider in fine weather than in bad weather, the reverse of what might have been expected. The stronger wind in bad weather would, if on-shore, cause particles of matter floating, or in suspension near the surface, to approach the shore; the waves also would break further from

* *Proceedings of the Institution of Civil Engineers,* vol. xxiii., p. 241, and vol. xl., p. 107.

† See further illustration of this point in note on p. 79.

the shore, and carry towards the shore material in suspension near the surface. In fine and calm weather there would be less to obstruct the motion seawards of particles of matter held in suspension near the surface.

33. Even when the waves are not removing material from one part of the slope to another, the bed of the sea near the shore—that is, in shallow water—must be in a state of perpetual motion, unless the sea is too quiet to stir the material of which the bed is composed. The finer the material the greater the depth of water in which it would be moved. Coarser material at a considerable depth and heavy material near the shore might not be similarly disturbed except by a heavy sea. The author has observed this action on a small scale through clear water. The sand, a little way from the water-line, was continually oscillating up and down the slope—towards the shore as each wave came in, and away from it as the wave returned. With large waves the motion would be similar at a greater depth. It is almost certain that, at times, this disturbance takes place at a very considerable depth.

(d.) Relation between Wave-action and the Slope of a Beach.

34. The effect of the slope on the waves, or the action of waves on different slopes, may now be considered. Not only boulders and shingle, but sand, merely, is sufficient, under certain conditions, to withstand the force of the waves, even in the heaviest sea. It will, however, be observed that where the seashore consists of sand, there is a very flat slope; where the material is shingle or small stones, under similar conditions, the slope is greater; and where there are large stones or boulders, the slope may be very steep. It will also be observed that below the water-line in each case, as a rule, the slope gradually becomes less and less; and further, where there is shingle on the beach, smaller and finer material is usually found below the water-line, sometimes sand only, and not shingle, is to be found below low-water level.

35. It would seem that, as shingle or sand is carried alternately up and down the slope, and boulders also in a heavy sea, the normal slope in either case is that which allows the usual waves so to break as to move the material to the same extent both up and down. If a little material in excess is moved upwards at one time, the irregularity is corrected by

more being moved downwards at another time, and *vice versâ.* The less slope of the sandy shore destroys much of the force of the incoming waves a long distance out, and causes the waves to break before reaching the shore. Several broken waves, one behind the other, may be observed in almost calm weather rolling in at one time on to a sandy shore. Each incoming wave having to meet several return waves, the power of each to carry material one way or the other is, in consequence, to a great extent neutralised. With a similar sea coming on to a steeper beach of shingle, the waves break much closer to the shore; but the shingle is better able than the sand to withstand the greater shock. A heavier sea, in both cases, would break further out, and the incoming waves having to meet a greater number of return waves, the excessive removal of the material of the beach would be checked, as above explained, notwithstanding the greater power of the waves. Doubtless all waves coming into shallow water lose much of their force, before they break, in causing oscillation of the material forming the bed.

36. It will be interesting, and will serve to illustrate this point, to inquire what would happen supposing the waves to break with too great force on a shore of sand or shingle, or when the slope of either of these materials might be too great. It has been already shown that some of the material stirred up from the beach would be carried up the slope and some down it. The steeper the slope the less would be the quantity carried up the slope and the more that carried down it. That carried downwards would be more in the case of fine material than with coarse material. In this way the slope would gradually be reduced to that best suited to the material, or to that which would enable the material just to withstand the waves. The force of the waves would at the same time be lessened by the reduced slope. An equilibrium would thus be gradually established.

37. The reduction of the slope may be seen on any steep slope of easily yielding material exposed to wave-action. At the water-line the bank is cut into, and the material drawn down the slope. Of course, the case of a slope too steep to permit of the material when wet standing by itself must not be selected. Where the slope is not so steep as to cause the material to slip from its own weight, the material can only be carried down by the action of the waves. The slope is thus gradually flattened, and this goes on till the

slope becomes flat enough to withstand the wave-action. Increased force of the waves in a heavy sea probably has less effect on the slope than is usually supposed, if that slope be the one best suited to the material forming the beach; the increased force is destroyed by the waves breaking further out. More important points, in the opinion of the author, are the rapidity with which the waves follow one another and, more especially, the direction from which they come on to the beach. On the seashore, where the action of the waves is perpetually varying, the slope may often change; though the author is of opinion that other causes are usually at work when the changes are considerable.

38. If the above reasoning be correct, as the shingle becomes reduced in size, as will be presently explained, in moving along the coast, the slope of the beach should gradually become flatter. Further, so long as shingle remains on the beach any sand formed by attrition of the pebbles against one another is liable to be drawn under the water-line, and thus to be lost to view ordinarily. The observations of the author lead him to believe that these two propositions will generally prove to be correct. Where such is not the case, or where the slope of any beach differs much from that of a beach exposed to similar wave-action elsewhere, it is probable that some other agency is at work.

39. If the author may refer to the Chesil Bank in illustration of this point, he would suggest that the steep slope on the southern side of that bank is due to the strong current which flows round Portland Island. This slope at the south-east end of the bank is given at 1 in $5\frac{1}{2}$, sometimes increasing to 1 in $3\frac{1}{2}$; at the other end of the bank the slope is flatter. After a gale, the slope sometimes decreases to 1 in 9. The slopes observed by the author in New Zealand, when the beach had its normal slope —that is, when it was not being denuded of shingle— was about 1 in 10, decreasing when the material became finer to probably 1 in 15, or thereabouts. When the shingle was being carried forward rapidly, a portion of the slope might become as steep as 1 in 4, but this was only temporary. More definite information regarding the normal slope of shingle is required.

(*e.*) *Illustrations of the Foregoing Remarks.*

40. It may serve to make clearer some of the foregoing remarks to state here the result of an examination, by the

author, of the beach along the Western Spit at Napier, about the time of high-water. Waves were coming from the north-east, and were breaking some few hundred feet off the most exposed part of the beach, the trend of which was north-west and south-east. Now and then as many as four broken waves were to be seen at a time one behind the other, although there was very little sea beyond, and elsewhere the waves were not breaking till close in shore. Coarse sand was on the beach, the slope of which was very easy. A short distance (100 to 200 yards) west, the waves were breaking directly on the beach, which was running in the same direction; the slope was steeper, and there was shingle, not sand. Further west, the beach curves towards the south-west, and then to the south. Here the waves scarcely broke; there was little more than a wash along the beach; the material was sand, with shingle higher up. In a sheltered bay further west the beach, running north and south, was steep, and formed of shingle; no waves were breaking on it. On going partly round the bay to where the beach runs east and west the waves were beginning to break again; the slope was flatter, and the material was coarse sand once more. Further round, where the beach trends to the north-north-west, there was fine sand, with a very easy slope; two or three small waves were flowing on it at one time, the furthest out breaking at a height of about a foot. Large pebbles projected above the sand in places, and here, as at other places where there was sand near the water-line, there was shingle higher up the slope. Further on, the beach taking a north-westerly direction, the material was coarse sand, with small pieces of shell. Beyond this the trend of the beach was more northerly, and the waves were larger.

41. The coarse sand above mentioned was found on closer examination to be really very fine shingle. It was met with in other places also. It appeared to the author at the time to be deposited by waves coming directly on-shore, as mentioned in the Appendix (*c*) to this paper. The following explanation is suggested:—After the beach has been partly or wholly denuded of its surplus shingle, the slope would be reduced from the water-line upwards for a certain distance. On-shore waves would now throw up material from below the water-line without the power of carrying it down again.

42. Some observations as to the action of waves from different directions (on the Chesil Bank ?) were made by Sir

John Coode. The main points are given in an Appendix to this paper, with the results of observations by the author. The two do not agree; but the former, being applicable to the locality where the observations were made, may apply to some localities in this part of the world. Both are given, as they may be useful to other observers. To assist in this, remarks as to the chief points of difference are added (see *b* in Appendix).

(f.) Summary of the Foregoing Remarks on Wave-action.

43. The following is a summary of the foregoing remarks on wave-action on a beach:—

(1.) Waves breaking on any beach stir up some of the material, and carry a portion up the slope.

(2.) The return waves wash some material down the slope, the force of the waves rapidly increasing till checked.

(3.) Return waves may, or may not, move as large stones down the slope as the incoming waves carried up it, depending on the slope being more or less steep than usual.

(4.) A return wave is not destroyed on meeting an incoming wave; the two cross, and continue their course. But the motion of the material held in suspension by the two waves receives a check which tends to cause the deposition of the heavier particles.

(5.) Waves breaking obliquely on-shore cause the material to advance along the shore in the direction the waves take; but waves breaking directly on-shore merely cause the material to move up and down the slope without altering its position laterally.

(6.) The lower part of a wave breaking on-shore has probably a backward (off-shore) motion, tending to carry material away from the shore.

(7.) Waves breaking at a distance from the shore stir up the bed of the sea, and material is in consequence carried away from the shore by the return waves flowing as an undercurrent.

(8.) Waves so breaking cause some of the material forming the bed to rise in the water. Such material on approaching the surface is likely to be carried towards the shore.

(9.) The bed of the sea near the shore is in a state of continued oscillation, unless when the sea is too quiet to move the material.

(10.) If the slope of the shore be too steep for the material of which it is composed, the waves have a tendency to draw material down below the water-line—that is, to flatten the slope. In consequence of this the force of the waves is reduced.

(11.) If the slope be too flat, material on being thrown up by the waves will be likely to remain on the beach, and thus the slope will be gradually increased. The power of the waves will be increased in consequence.

IV.—Movement of Shingle along the Shore.

44. The way in which the waves cause the shingle to travel along the shore having been explained, the effect of the varying directions of the wind, and of the waves resulting therefrom, on a coast of very irregular outline may be first noticed under this head. In connection with this matter, it must not be overlooked that waves on coming into shallow water have a tendency to shift round a little towards the coast, and thus strike more directly on a shore than the direction in which they are moving in the open sea would seem to indicate. Shingle will not only move at varying rates at different times, but on many, perhaps most, parts of the coast it will move sometimes in one direction and sometimes in the opposite direction, though, as a rule, there is decidedly a greater movement one way than the other. Waves will impinge at different angles on different parts of the coast, and will sometimes drive the shingle entirely away from an exposed point. In this way some cliffs, which are at times protected from the sea by a beach of shingle, are at other times much cut away. But even where a beach is never thus entirely denuded, very great differences in the quantity of shingle are generally noticeable at different times.

45. Another point not to be overlooked is that, although the quantity of shingle in motion may be constant, it may, nevertheless, appear to be different at different points. Where the trend of the coast favours a rapid movement one way, the width of beach is likely to be less than where the movement is less constantly in one direction, or the waves strike with less force. In other words, the sectional area would be in inverse ratio to the mean velocity.

46. As shingle is carried along it is gradually reduced in size; large stones are reduced to small pebbles, and small pebbles to sand. The softer the material the more rapidly the reduction takes place. This reduction is not, however,

regular along the coast. Where the movement along that portion of the coast fully exposed to the prevailing seas is rapid, the shingle might appear to be of one size for a long distance; where the trend of the coast is different—is partly sheltered from the prevailing seas, or is much exposed to seas from other directions, giving rise to a contrary movement at times—the movement of the shingle in the prevailing direction being less rapid, it is likely to be reduced in size in a comparatively short length of coast.

47. Shingle may disappear at certain points of the coast-line notwithstanding the supply is continuous. It will be well to consider how this takes place. Wave-action does not ordinarily carry shingle of any size much below low-water level, except where, from some cause or other, a steeper slope than the normal exists. A current flowing round a point, or a current sweeping round a bay, may remove the finer material forming the base of the shingle, and may thus increase the slope. In such case some shingle will probably be carried below low-water level by the action of certain waves, as, for instance, waves breaking at long intervals, and allowing the return wave to act with the greatest effect. But, when the beach has its normal slope, shingle may disappear under the following circumstances:—

(1.) The fresh water, or tidal, flow at the mouth of a river or lagoon must carry below the water-line any shingle that may be thrown into the stream by wave-action or otherwise, especially at the point of each tongue of shingle, which is generally formed where a break in the beach occurs from the above cause.

(2.) As the shingle is worn and reduced in size, the finer particles are carried under the water-line, while the shingle remains on the beach.

(3.) Where a shingle beach appears to die out gradually, running into sand, the slope becomes flatter and flatter as the shingle changes to sand. Then, the sand, if not accumulating, notwithstanding the continued travel of the shingle towards the spot, must be drawn under the water-line, and tend to raise the sea-bed. It goes, in fact, as is very commonly the case, to silt up the head of the bay.

48. It may have been noticed in a former part of this paper that the formation of a lagoon by a strip of shingle beach is not unfrequent on these coasts. This occurs at a point where, before the shingle beach was formed, a deep indentation in the coast-line existed. Owing to the shore-

line suddenly receding, the wave-action must have been insufficient to drive the shingle along the shore of the bay as fast as it accumulated at the commencement of the indentation in the coast-line. The shingle would then be deposited in a line between the points of the shore terminating the bay. No such action takes place, ordinarily, across the mouth of a bay when the waves can break fairly on the shores of the bay, as in Caroline Bay at Timaru, and at the present time north of Napier. Other instances are to be found where the shore-line, along which shingle is moving, suddenly recedes and, being protected in some way, the wave-action is insufficient to drive the shingle along the receding shore-line as fast as it accumulates at the point. The point will then advance steadily further and further out. This was probably the action going on south of Napier before Scinde Island was connected with the mainland. Similar action is going on at Hurst Castle and Dungeness, on the south coast of England, and at other places.

49. As the action at the mouth of the River Ngaruroro, six miles south of Napier, is due to a similar cause, the case may here be briefly described. The mouth of this river has been for some time past shifting steadily northwards, the shingle travelling from the southwards. The shore behind the shingle is formed of earth, and would be easily cut away but for the shingle beach in front. The line of the beach is fixed, and could be altered but slowly. The stream from the river having first worked as far northwards as the bank would allow, began to cut away the bank and to form a channel behind the shingle.

50. This has gone on, the river near the mouth having changed its course, extending further and further north, parallel with and behind the beach, and cutting away more and more of the original shore, and would go on indefinitely if there were only a steady fresh-water stream to form the current. When heavy floods come down the river at intervals, a fresh mouth is opened through the shingle, when the water can more easily escape in this way than along the channel. The old mouth of this channel is then quickly closed up by the shingle, and that opened by the flood continues in use; but, as before, it gradually shifts more and more to the north, and the same action as before goes on. If the channel were kept open by the tidal flow, this flow would gradually become less and less as the channel lengthened, and the mouth of the channel

would get smaller, and at length it would close up altogether. Several of the smaller rivers on the Ninety-mile Beach appear from the chart to be so circumstanced (see par. 10). The water of the rivers then would either filter through the shingle, or it would accumulate till it was able to force its way through now and then.

51. The mouth of the River Tuki Tuki, two miles south of the River Ngaruroro, is at present more constant than that of the latter river. The author attributes this to the very large mass of shingle which is lying in front of the former river. The tendency is for the mouth to shift northwards, but the large mass of shingle is not quickly cut away, and, before any great change can be made, a flood coming down the river brings the opening in the shingle opposite the mouth of the river once more. It is easier for the smaller river, Ngaruroro, to cut away the earthen bank, than for the larger river, Tuki Tuki, to cut away the shingle. The author was informed that several rivers of New Zealand are subject to frequent and heavy floods for a series of years, and then the reverse is the case for another series of years. This is expressed, in other words, by there being a cycle of wet seasons at intervals. When the time comes for the floods of the rivers to be less for a few years in succession, the shingle will be less frequently broken through, and then the mouth of the River Tuki Tuki may shift like that of the River Ngaruroro; probably both will have one and the same mouth for a time.

V.—Movement of Shingle Below the Water-line.

52. This is a matter upon which the author is not prepared to say much. Although there may not ordinarily be any tendency for the shingle to descend below the water-line, so long as the beach is continuous and has its normal slope, and the movement of the shingle is unobstructed, this will happen when a sudden change in the trend of the coast-line occurs, as mentioned above (in par. 48), or when a break occurs in the beach at the mouth of a river or other channel which is kept open by a strong current of water. In such a case a spur is formed in the direction the shingle is moving. This extends a certain distance, depending on the strength of the current and the force of the waves; the current has to force its way on the one side, and the waves of the sea on the other side either driving the shingle towards

the shore or keeping it in the direction necessitated by the slope of the bed of the sea. The shingle is at length forced over into the water, and forms a bar where the waves break; over this the current from the river flows.

53. The shingle being forced into the water would fall to the bottom as soon as the forces acting on it failed to keep it in suspension. Here it would accumulate till it raised the bed or formed a bar across the channel just sufficient for the current to pass over it without disturbing it. Any shingle in excess of this washed into the bed would, with the current on the one side and the waves on the other, be forced across the channel, when it would be thrown up again on to the beach. It is impossible here to analyse the action going on; it must suffice to state the fact.

54. The depth at which this action would take place would vary according to circumstances. Thus, before the channel leading to the inner harbour at Napier was contracted by the present moles, the bar was at times not more than 4 or 5 feet at low water. It will obviously be as little as the current will permit. The important point to ascertain is, what is the greatest depth at which the action will go on?—in other words, what depth can be obtained and maintained over a bar where there is travelling shingle? Reverting to the case of the Napier channel, all attempts to keep it clear have, except when the shingle was trapped for a time behind the east mole, failed to secure for any length of time a greater depth than 8 or 9 feet at low water. During westerly weather, in the summer, a foot or two more may be obtained; but the depth is reduced by heavy easterly weather. There is a very strong current through the channel—six to seven knots an hour in mid-stream—and yet the above-mentioned depth only is obtainable. A slightly weaker current might not make much difference; but if the current could be reduced considerably in strength, the depth of water over the bar would certainly decrease. A stronger current would probably cause the bar to move further from the mouth without improving the depth in any way; or it might increase the depth, and at the same time form a long spit in a direction between that of the beach and that of the stream, diverting the latter and causing the channel to curve round.

55. Mr. C. H. Weber, late engineer to the Napier Harbour Board, who very carefully observed the action going on in Hawke's Bay during many years, prepared a memorandum

for the information of Sir John Coode, which is dated 20th March, 1879. In it he remarked:—"The depth at which the shingle travels can be judged to some extent from the difference in the soundings north-west of the Bluff. The cavities in the bottom, 15 feet below water, are found emptied of shingle after easterly weather." Around the Bluff the sea has "a very uneven bottom, which traps the shingle in its journey round the Bluff. Soundings have proved that, in this very exposed locality, shingle travels to the depth of fully 18 feet."* It may be open to question whether the movement of shingle at this depth is due entirely to wave-action, or is partly due to a current flowing round the Bluff;† also, whether much of this shingle is thrown up again from a depth of 18 feet on to the beach or not. Much depends on the size of the waves at the point.

56. The important point to consider here is, whether the fact of shingle shifting at a depth of 18 feet at the Bluff can be taken as evidence that it would cross the bar at the entrance to the present harbour at such a depth or not. In face of the other facts before referred to‡—that during westerly weather (when the shingle would be driven backwards) the depth increases, but easterly weather (which drives the shingle forward) reduces the depth again—the author cannot admit that any such depth on the bar could be maintained so long as the supply of shingle is unchecked. If this depth were obtained in any way, the author is of opinion that the shingle would not cross the entrance; it would accumulate till the bar became nearly as at present, and then it would begin to travel once more.§

57. A depth of 8 to 10 feet would therefore appear to be the maximum at which the shingle can travel freely in this case. Under altered conditions a different depth would perhaps result. Further observations are necessary before anything more definite can be stated on this point. One thing, however, is scarcely open to question: no harbour suited to vessels of any size can be secured where there is travelling shingle, unless means be adopted to keep the shingle from the entrance.

Concluding Remarks.

58. The following deductions from the foregoing remarks regarding shingle on the beaches visited by the author are

* See note on p. 79. † See par. 31. ‡ See par. 54.
§ See Appendix II., at p. 84.

given as a summary. Many of these deductions may be of general application:—

(1.) Shingle is caused to move up and down the slope of any beach by the action of the waves, and is reduced in size by constant attrition.

(2.) Shingle is caused to travel along the coast by waves striking obliquely on the shore.

(3.) Shingle of any considerable size is rarely carried much below the water-line by wave-action alone. On the contrary, waves tend to throw up on to the beach material from the bed near the shore. At times very heavy stones have been so thrown up. The finer material is carried down again by the return waves.

(4.) There is a certain slope, peculiar to each size of shingle, which may be called its normal slope, and which enables a shingle beach best to withstand the action of the waves. The larger the shingle the steeper its normal slope, and *vice versâ.*

(5.) The *tendency* of wave-action is to arrange the shingle in regular order on a beach, as follows:—

- (*a*) The largest pebbles to collect near the water-line, or between the levels of high and low water. The size should diminish slightly from high-water level upwards, and very rapidly from low-water level downwards.
- (*b*) The slope will be steepest between the levels of high-water and low-water. Above high-water level the beach will assume a convex shape; below low-water level the profile of the bed will be concave.
- (*c*) With a slope flatter than the normal, the largest shingle ought to be at, or above, high-water level. With a slope steeper than the normal, the large shingle should be looked for near low-water level.
- (*d*) If the slope differ from the normal, the wave-action tends to restore the slope, reducing it if too steep, and increasing it if too flat.

The theoretical results are seldom attained, owing to the perpetual changes going on. The longer the forces at work remain constant, the nearer the theoretical condition is approached.

(6.) When the shore runs in one, or nearly one, direction for several miles, without any projecting points or bays to break the uniformity of the coast-line, shingle will be uniform in its character.

(7.) Where the coast-line is irregular so that the movement of shingle is likely to be arrested at times, great changes in the beach may be looked for. The shingle will sometimes accumulate, and at other times the excess will be removed. In places the beach may be almost, or entirely, denuded of shingle.

(8.) When an accumulation of shingle takes place at any point, the beach is raised. This may be called a "high" beach. In this case low-water mark may extend further out from the shore than usual.

(9.) When the surplus shingle is in process of removal, being carried along the coast, a flat slope is formed from the water-line upwards. This may be called a "low" beach. At the upper edge of this low beach is a steep slope between the low beach and the high beach. This slope gradually recedes further and further from the water-line till the surplus shingle is entirely removed.

(10.) A high beach will have a steeper slope, and will consequently be formed of larger shingle, than a low beach.

(11.) Shingle is lost from the beach as follows:—

(*a*) By being carried below the water-line by streams, flowing across the beach into the sea, and by wave-action at each projecting point of the beach.

(*b*) By the finer particles being separated from the shingle, and drawn under the water-line all along the coast.

(*c*) By the remainder being gradually reduced to sand.

(12.) When the supply of shingle at any point, where its movement along the coast is arrested, is too great to permit of the whole being reduced to sand, the shingle accumulates. If this accumulation occurs against a cliff, or where waves break with great force, a high bank is likely to be formed; but if the accumulation occur where the ordinary wave-action on a beach takes place, the shingle is arranged in successive ridges one in front of the other.

(13.) Where there is travelling shingle, a bar will form under the following conditions:—

(*a*) Across the entrance to a river or lagoon. The depth of water over this bar is not likely to exceed 8 or 10 feet at low water.

(*b*) From any point where the trend of the coast-line suddenly changes, or from the end of any jetty or other similar projection from the shore.

(14.) Shingle may travel in other situations at considerable depths. It has been observed to do so to a limited extent at as great depths as 6 and 8 fathoms. But whether shingle is thrown up again from such depths on to the beach is doubtful.

(15.) These propositions need to be confirmed by further information before they can be considered of general application.

59. This paper has extended to a much greater length than the author anticipated, and is not so complete or satisfactorily arranged as he would have liked. He trusts, however, that it may not be without interest to members. Much remains to be learnt regarding the movements of shingle, even in the cases dealt with in this paper. Observations elsewhere require to be made before general conclusions can be safely drawn. The author has, nevertheless, attempted to generalise to some extent, in order that others may be the better able to make use of what he has written; for a bare relation of facts of this nature is, as a rule, of very little use unless the facts are connected and the principle underlying them explained in some way. The author trusts that any errors into which he may have fallen will be pointed out, and that some one else having opportunities of observing the action of shingle will be induced to give some further information on the subject.

60. To facilitate the collection of information of an uniform character, a few points which ought to be noted are mentioned in the Appendix (*e*—p. 84). Such particulars collected from different localities would be comparable and would probably soon remove most of the difficulties which now surround the subject.

Note to Par. 55, regarding Wave-action at considerable depths (see also par. 29 *et seq.*):—

On a rocky bottom, small stones and sand would be very liable to be scooped out of crevices and hollows and forced to rise to the surface by wave-action; while a similar result would not take place, at the same depth, on a homogeneous bottom, which would yield equally in all directions. A rocky bottom would reflect the waves.

APPENDIX.

(See par. 42.)

(1.) Result of Sir John Coode's Observations of Wave-Action on Shingle.

(a.) Extracts from Proceedings of the Institution of Civil Engineers (Vol. XII. pp. 539-541) :—

"An examination at low-water with the wind off-shore, or just along the shore, will show that, as a rule, the largest shingle to be found on any particular beach, at that particular time, is just about the level of the previous high-water, or so far above it as the wash of the previous tide may have extended; and the size decreases from this down to low-water."

"After the prevalence of heavy on-shore winds, or a 'ground-swell,' the large shingle will be found to be entirely scoured away from the beach." "Shingle accumulates upon any beach with off-shore winds, whilst it is carried off, or scoured away, during on-shore winds, and more especially by the ground-swell which follows."

"Seven, or any less number of waves per minute, indicate the destructive action, and nine, or any greater number, the accumulative action; but no very precise rule can be framed upon this basis." "A more certain indication is found by watching the course of the water as it falls from the crest of the wave after breaking. If it falls upon the water which may be returning down the slope from the wave immediately preceding—as it will do when the waves follow in rapid succession—this may be taken as an evidence that the accumulative action is going on. If, on the other hand, the water descends directly upon the pebbles—as is the case when the waves break at comparatively long intervals—it carries down with it a portion of shingle, and is, in fact, a case of destructive action."

The cross-section or profile of the Chesil Bank, near the west end, taken after a gale, was very nearly a "parabolic curve from a point more than 25 feet above high-water level down to a little below high-water level." The slope between high-water and low-water levels was, after the same gale, "slightly flatter than 1 in 9; and precisely the same inclination has been observed, within the same limits, after a heavy ground-swell. . . . After a continuance of off-shore winds for two or three days, the case is very different. Under such circumstances, the shingle takes a perfectly uniform inclination, within the limits of the tidal range, and lies generally at a slope of 1 in 3½ to 1 in 4."

(b.) Remarks by the Author on Sir John Coode's Observations.

The "on-shore winds" would, as a rule, be accompanied by waves from the same, or nearly the same, direction as the wind, and striking the shore obliquely or at right angles as the case may be; but the "off-shore winds," or winds just along the shore, would be accompanied by waves from some other direction than that from which the wind might be blowing. Whether the waves strike the shore obliquely or nearly at right angles—very important considerations in relation to the movements of shingle—is not known from the description given by Sir J. Coode. In all cases, it would be far more satisfactory if the direction and character of the waves, rather than of the winds, were described. The term "ground-swell" also is vague.

The scouring away, or destructive action, mentioned by Sir J. Coode, is, in the opinion of the author, really the surplus shingle, which has been accumulating for a time, being carried forward by waves striking the shore obliquely. This gives the appearance of some having been cut out, leaving a steep slope above the water-line. The sectional area of the shingle in motion is simply reduced to correspond with the more rapid advance of the shingle. In the case of the steep slope of the Chesil Bank (1 in 3½ to 1 in 4), the general action of on-shore *waves,* especially if following one another at long intervals, must be to cut into the bank—that is, to reduce the slope above the water-line.

With regard to the effect of waves striking the shore at different intervals, another observer, Mr. H. R. Palmer, remarked—"that when ten breakers arrived in a minute, the destructive action was but just commenced, and when only eight breakers . . . the pebbles began to accumulate." These results, it will be observed, differ from those stated by Sir J. Coode. Perhaps Mr. Palmer referred to the lower part of the beach, and Sir J. Coode to the upper part.

The water falling from the crest of a wave after breaking "upon the water which may be returning down the slope from the wave immediately preceding," is understood by the author to mean a meeting of the waves on the slope, in which case the downward movement of material would be arrested, and the cutting-out action consequently prevented. Any shingle thrown up by the waves would then remain on the beach. When "the water descends directly upon the pebbles, as is the case where the waves break at comparatively long intervals," the return waves are able to act with full effect, and, the slope being steep, the destructive action goes on freely.

(2.) Results of Observations by the Author.

(*c.*) *Results Noted.* (See par. 41.)

The author did not notice the different effects of off-shore and on-shore winds, as above; but the difference resulting from waves coming *obliquely* on-shore, and from those coming *directly* on-shore or striking the shore nearly at right angles, was most marked, particularly near the time of high-water, when the lower portion of the beach would be submerged.

Waves coming obliquely on-shore appeared to scoop out the shingle, to throw back the beach, and to form a steep slope with large shingle on it. These observations apply more particularly to the upper part of the beach; the lower portion, when it could be observed, was usually flatter than before.

Waves coming directly on-shore, or striking the shore nearly at right angles, appear to form a flatter slope, to widen the beach, and often to cover it with fine material, which when wet appeared from a little distance like mud; but on close examination it was found to be coarse sand, formed of material similar to that of the shingle. These waves would draw down the shingle from the steep slope formed by waves striking the shore obliquely, and raise the lower part of the beach; and further, as material is not carried along the shore by these waves, fine shingle or coarse sand thrown up on the lower and flatter part of the beach must remain there.

(*d.*) *Modifications of the above probably necessary under certain conditions.*

The author doubts whether the effect of waves striking the shore, either obliquely or at right angles, would be always as above. The results stated were observed shortly after there had been a full beach, surplus shingle having formed what may, perhaps, more accurately be described as a high beach. Consideration of the subject, since the observations were made, leads the author to believe that after the denuding of the beach of its surplus shingle and the forming of a low beach, the result of waves continuing to strike the shore obliquely would depend chiefly upon whether there were, or were not, a further supply of shingle ready to be carried on to the portion of the beach under observation; that is, whether there were surplus shingle lying near on the side from which the waves were moving or not.

If there were a further supply of shingle, the lower part of the beach would probably not be flattened to any great extent by waves striking the shore obliquely; or, if flattened for a time during changes in the weather, it would be covered shortly with fresh shingle. If there were no further supply of shingle, the beach would be still further denuded, would be reduced in width and have a still flatter slope; the material would probably become smaller and smaller and in time perhaps sand only would be visible above the water-line. This action would go on till the beach disappeared altogether, or became so much reduced as to afford no protection to the shore which, if of yielding material, would begin to wear away.

The result of waves striking the shore nearly at right angles, when there was a full beach down to low-water level, would probably not be noticeable during a short period of time, unless in the exceptional case of the slope below low-water level being steeper than above that level. In such a case, these waves would tend to draw the material downwards, make the beach wider, and gradually reduce the slope. Fine material would not be thrown up unless the slope became very flat from some other action going on at the same time. Long continued action of waves nearly at right angles on a full beach would gradually reduce the material by constant attrition; the finer particles would then be drawn downwards under the water-line. In this way, shingle moving towards one part of a beach may slowly disappear, instead of accumulating, as it does when the supply is too large to be all disposed of in this way.

(*e.*) *A few points to be noted when observing the movements of shingle.* (See par. 60.)

Besides the main features of the locality and the state of the weather at the time, it is important to ascertain what the weather for a few days previously has been, and the corresponding action on the beach. Not only the direction of the wind but the direction of the waves with reference to the shore should be noted. The approximate height of the waves, the number of waves per minute, and whether the water falling from the crest of the waves, as they break, strikes directly on the beach or on to a cushion of water, may be usefully observed. The general form of section, or profile, of the beach should be recorded, with the state of the tide at the time of observation, remembering that, except at low-water, the whole of the beach would not be visible. Any information regarding the material and slope below the water-line, when obtainable, is likely to be particularly useful and instructive. Observations should be carried on for as great a length of beach as possible, carefully noting the bearing of different portions, if not uniform, and ascertaining whether the beach is full or empty at each part, or, in other words, whether there is more or less shingle than usual.

Appendix II.

Travel of Shingle below the Water-line.

(See par. 56.)

Since writing the paper, the author has come across a case where the travel of shingle is interrupted by deep water. This occurs at Harwich, on the east coast of England. Shingle works down the coast from the north and has formed, partly across the combined mouth of the rivers Orwell and Stour, a long spit called Landguard Point, which advanced in a southerly direction some 700 yards between the years 1760 and 1865. In the last twenty-five years of this period, the advance was nearly 300 yards; this rapid elongation being accompanied by a thinning out of the point, there being an evident tendency to form a long spit entirely across the mouth of the channel, as has occurred a few miles to the north of Harwich. The *North Sea Pilot* states that between 1804 and 1826 there was "a narrow seven-fathoms channel close to the walls of Landguard Fort." In 1826, the point advancing, gradually "reduced the available depth into the harbour to 11 feet." About 1845, dredging was commenced; this has increased the depth to 17 feet at low-water springs, which was the depth in 1874.

The point to which the author wishes to draw special attention is that at one time no shingle seems to have crossed the channel. Then, as the depth was reduced, shingle began to give trouble on the south side; and latterly, it would appear from various accounts, the shingle has decreased again. The conclusion forced on one is, that with a depth of 11 feet, some shingle crossed the channel, but that with a depth of 17 feet or 18 feet it does not cross under ordinary circumstances. During heavy weather, some small quantity may be carried across the increased depth.

It may be interesting to note here that sand has formed a similar spit, called Spurn Point, partly across the mouth of the River Humber. The depth at which this material can cross the channel would appear, from the soundings given on the chart, to be from 40 feet to 45 feet.

These two instances are not conclusive, because the chain of circumstances is not as complete as could be desired; but they help to support the author's arguments. They show that shingle does not cross freely a channel the depth of which exceeds 11 feet or so, and that the lighter the material the greater the depth at which it can travel. It may be remarked here that the shingle on the east coast of England is, by all accounts, smaller than that on the east coast of New Zealand. In this case, the former would be able to travel at a greater depth than the latter.

Art. V.—*Notes on the Electroscope.*

By Professor Andrew.

[Read 8th May, 1884.]

Art. VI.—*On a Recent Shower of Mud-stained Rain.*

By R. L. J. Ellery, F.R.S., F.R.A.S.

[Read 8th May, 1884.]

Art. VII.—*Suggestions for Reducing Excessively High Temperature in Ships and Buildings.*

By J. Lockhart Morton, Esq.

[Read by the Hon. Secretary, 12th June, 1884.]

In the present age, when applied science is being so much directed to mitigate human suffering or to benefit the race, it may be worth while to consider what new direction may be given to any of the recent discoveries, in the hope that something, however little, may be done to make life more enjoyable to those in health, and to reduce the suffering and distress of invalids, and of the sick and the dying.

About twelve or fifteen years ago I took occasion to suggest, through a London paper, how pure air might be supplied to houses in large cities by compressing air in the country and forcing it through pipes to the chambers of sick people or to hospitals. This could not be done on a very extensive scale, or, indeed, at all, without a great loss of power, for, in compressing air to be forced through tubes to a distance from the compressing engine or water-power, much of the applied power is necessarily lost. I was aware that great heat is evolved by compressing air, having often seen fire procured by suddenly compressing air in a tube a few inches in length with a little tinder placed at the bottom, to which a piston was driven down by a blow with the palm of the hand ; but, as my idea was to supply pure air discharged through a small tube from which heat would be absorbed as it expanded to escape, I calculated that the temperature of a room would not become much reduced, and, as there would be no occasion for the discharge to be constant, it could be turned off by a tap. I do not know if my communication was published. Probably the editor thought that, coming from Australia, it was unworthy of any consideration.

On reading recently the very interesting paper read by Dr. Cutts before the Medical Society of Victoria, especially that portion of it referring to the intense heat which has to be endured by every one on board the mail steamers in tropical regions, but chiefly in the Red Sea, where persons in delicate health, returning to their native land from India or the Colonies, almost invariably die or experience great distress, in consequence of the fearful and excessive heat by night and day, from which, as Dr. Cutts says, there is no escape—the sea-water itself being nearly of the same temperature as the atmosphere—I at once thought it would be an easy matter to overcome such fatal heat. I may mention that, on communicating my ideas on the subject to Dr. Cutts, he advised me to bring them into public notice.

When we have on many of our passenger steamers appliances for keeping beef and mutton in a frozen state throughout the whole voyage, why should living human beings in the saloons or on deck be exposed to such high temperature as to cause suffering and death ? It seems nothing short of an oversight to keep everything within the meat chamber frozen, and yet permit men, women, and children in the saloons, between decks, or even on the deck, to suffer or die from excessive heat.

It seems only necessary to make a suggestion that living human beings are as worthy of being taken care of and preserved as beef and mutton, to find that it will be promptly accomplished. I will venture to predict that, when this subject is once fairly considered, there will be an immediate application of the refrigerating process by the expansion of dry compressed air to all steamers carrying passengers through the tropics, as well as to hospitals, legislative chambers, town halls, and, perhaps, to private houses in hot summer weather in tropical or sub-tropical countries.

All that would be necessary to moderate the temperature in saloons or between decks in steamers would be to provide a few small tubes fitted with stop-cocks to discharge dry compressed air within them. These should be overhead, as the expanding cool air in absorbing heat from the surrounding atmosphere would have a tendency to descend, whilst the warmer air below would have a tendency to rise and mix with it. Thus, in a few seconds, the temperature of the air within the whole space would be reduced.

No arrangement for reducing high temperature in passenger steamers or ships would be complete unless it could be applied to both decks as well. The difficulty in reducing high temperature in the open air, say on the poop or main deck, would be greater than in the saloon or between decks, but I do not think it would be insurmountable. A few small tubes provided with stop-cocks should be placed overhead under the awning, and a few also in the fore part of the main deck and poop. In calm weather these would be available, especially the latter, for in the forward motion of the vessel the cool air would drift aft towards the stern. Should a wind blow from either quarter, I assume that a curtain would be placed to windward to protect the passengers. Movable standards with flexible tubes, so that they could be shifted to suit the direction of the wind, would, perhaps, be most serviceable with a wind from either quarter.

It would be a great gain to have this suggestion carried out between decks. It could be applied subsequently to the upper deck in the best way to be determined by experiment.

Art. VIII.—*Experience of the Barque "W. H. Besse" in the Java Earthquake, August,* 1883.

By Mr. G. H. Ridge.

[Read 12th June, 1884.]

Some days ago Captain Gibbs, of the American barque "W. H. Besse," spoke to me of his experience in the Java earthquake (he being at that time chief officer). The vessel was on a voyage from Manila to Boston. I thought that any information I could obtain of such a terrible disaster would be of interest to the members of the Royal Society, and I requested permission to look at the chart and make extracts from the log-book, which was readily granted. On looking at the chart of Sunda Straits, although they had only been partially re-surveyed at the time the "W. H. Besse" left Boston for Melbourne, I found that a large portion of Krakatoa Island had been submerged; two new islands and a large reef have appeared where deep water was previously indicated. During the time of the earthquake the shower of ashes was so heavy that they covered the deck to a depth of five or six inches, and the darkness so intense it was almost impossible to distinguish an object a few inches distant. The day following the crew were engaged most of the day in throwing the ashes overboard. The captain filled a small cask out of those that had fallen on the sails. The present chief officer, not knowing that the captain desired to bring them to Melbourne to distribute amongst his friends, used most of them when scrubbing paint-work. However, I am pleased to say I obtained a small quantity and handed them to our worthy president for microscopical examination and analysis. I shall now proceed to read the extracts taken from the log-book :—

Friday, 24th August.

"Off Amsterdam Island. Moderate winds and cloudy weather; barometer 30·14, thermometer 95."

Saturday, 25th August.

"Moderate winds and fine weather; barometer 30·15, thermometer 90."

Sunday, 26th August.

"The day commenced with strong breezes and thick, cloudy weather, barometer 30·15. At 4 a.m. hove short, and at 6 a.m. got under weigh, wind south-west. At 4 p.m., wind hauling ahead, came to an anchor, the sky at this time having a threatening appearance, atmosphere very close and smoky. At 5 p.m. heard a quick succession of heavy reports sounding like a broadside of a man-of-war, only far louder and heavier; heard these reports at intervals throughout the night. The sky was intensely dark, the wind having a dull moaning sound through the rigging; also noticed a light fall of ashes. The sun, when it rose the next morning (Monday, 27th August), had the appearance of a ball of fire, the air so smoky could see but a short distance. At 6 a.m., thinking the worst of the eruption was over (as the reports were not so frequent or heavy as during the night), got under weigh. Having a fair wind, was in hopes to get out clear of the Straits before night. At 10 a.m. were within 6 miles of St. Nicholas Point, when we heard some terrific reports; also observed a heavy black bank rising up from the direction of Krakatoa Island. The barometer fell an inch at once, suddenly rising and falling an inch at a time. Called all hands, furled all sail securely, which was scarcely done before the squall struck the ship with terrific force. Let go port anchor and all the chain in the locker; wind increasing to a hurricane. Let go starboard anchor. It had gradually been growing dark since 9 a.m.; by the time the squall struck us it was darker than any night I ever saw—this was 12 o'clock noon. A heavy shower of ashes came with the squall, the air being so thick it was difficult to breathe; also noticed a strong smell of sulphur—all hands expecting to be suffocated—the terrible noises from the volcano, the sky filled with forked lightning running in all directions, making the darkness more intense than ever. The howling of the wind through the rigging formed one of the wildest and most awful scenes imaginable—one that will never be forgotten by anyone on board—all expecting that the last day of the earth had come. The water at this time was running by us in the direction of the volcano at the rate of twelve miles an hour. At 4 p.m. wind moderating, the explosions had nearly ceased, the shower of ashes was not so heavy, so was enabled to see our way round the decks. The ship was covered with tons of fine ashes resembling pumice-stone. It stuck to the sails, rigging, and masts like glue, so it was weeks before it was removed, some of it still remaining on the wire backstays. One seaman was severely injured by walking off the forward house; he died the day after the ship's arrival in Boston. All day Tuesday, 28th August, crew were employed in shovelling the ashes off the decks, clearing the cables, and heaving up one anchor. Wednesday afternoon, 29th August, got under weigh. Was abreast of Anger at 8 in the evening; saw no lights on shore or signs of life. Although a fair wind, furled all sail but topsails. Kept on our course slowly, and cautiously heaving the lead every few minutes. At daylight the Straits were covered with trees, so it was difficult finding a passage through them. Passed a large number of dead bodies and fish, and thousands of green cocoanuts. At 6 p.m. were outside of the Straits. The ocean for 600 miles was covered with ashes and lava, the water for 1000 miles having a dull grey colour. Five of the crew were taken sick with the Java fever the day after leaving the Straits. Buried one man at sea. After rounding the Cape experienced a very heavy gale in the Gulf and bad weather on the coast, with only five men to work the ship, and those completely laid up by the time we got a pilot on board off Highland Light, one seaman dying the day after we arrived, and several more going to the Hospital."

Art. IX.—*Descriptions of New, or Little Known, Polyzoa.*

Part VII.

By P. H. MacGillivray, M.R.C.S., F.L.S.

[Read 10th July, 1884.]

Family, Cellulariidæ.

Maplestonia, n. gen. Plate I., fig. 9.

Polyzoary consisting of series of single and geminate cells, connected by distinct, corneous tubes. Cells with the front wholly occupied by a membranous area, or with the lower part filled in; imperforate behind. No avicularia or vibracula.

M. cirrata.

Portland, Mr. Maplestone; Warrnambool, Mr. Watts.

M. cirrata seems to be very rare, and I have only had an opportunity of examining three or four specimens. It occurs in minute purplish tufts, the branches curling inwards. They are arranged in series of single and geminate cells. In the single cells the front is usually entirely membranous, the margins being thick and bevelled inwards; in the geminate cells the lower part is usually filled in by the cell wall. The posterior surface is imperforate, and generally marked by transverse, faint lines. The mode of branching is very irregular. In all cases of geminate cells, each gives origin to the first of a series, but in some cases two branches spring from the summit of a single cell, or they may originate from the sides of a cell. There is no appearance of avicularia or vibracula.

Family, Salicornariidæ.

Cellaria rigida, n. sp. Plate I., figs. 1, 2.

Polyzoary regularly dichotomously branched; branches cylindrical, slightly arcuate, usually enlarging upwards. Cells mostly rhomboidal, pointed above and below; mouth in the upper half, lofty, slightly contracted towards the straight lower lip; operculum with, on each side, a cervicorn mark, and posteriorly a projecting, somewhat wedge-shaped process for the attachment of the occlusor muscles. Avicularium very large, replacing a cell; mandible of great size, nearly semicircular. Ovarian cells rounded above, narrowed below; the pore semilunar, at the extreme upper end of the cell, with the lower edge usually projecting and smooth or obscurely crenulate.

Port Phillip Heads, mostly on Dictyopora.

This fine species forms tufts 1 to 3 inches high. The articulations are frequently rigid from calcification. The internodes are thick, and usually slightly curved. The cells are nearly regularly rhomboidal; the ovarian cells broad, and rounded above, and narrowed below. The mouth is situated in the upper half, the lower lip corresponding to about the middle of the cell; deep in the interior are two sharp, stout, calcareous denticles from each of the upper and lower margins, directed vertically upwards and downwards. The operculum is very peculiar. It has a large cervicorn mark on each side, and the occlusor muscles are attached to projecting, wedge-shaped processes. The avicularium is of great size, replacing a cell; the upper margin projects much forwards, and the mandible is very large, nearly semicircular, and directed upwards. The ovarian pores are mostly semilunar, situated close to the upper margin of the cell, and about the same width as the mouth; the lower edge projects upwards as a sort of lip, which is either smooth or very faintly crenulate.

Cellaria Australis.

When I first described this form in Decade V. of *M'Coy's Prodromus,* I had not had an opportunity of examining specimens of the European *C. fistulosa,* and somewhat doubtfully considered it as a variety of that species. After examination of specimens kindly sent by Mr. Waters and Mr. Hincks, I am now quite satisfied that the present is a totally distinct species, and Mr. Hincks is inclined to the same opinion (*Ann. and Mag. Nat. Hist.,* May, 1884). The mode of growth is quite different. All the other *Cellariæ* with which I am acquainted are regularly, dichotomously branched, while in *C. Australis* the branches arise by corneous tubes from the surface of cells (or spaces representing cells), from the sides of the parent branches, and not from the extremities. Frequently three or four spring from different parts of one cylinder. They are all directed upwards, and are frequently nearly parallel to that from which they have risen. The cylinders are very much thicker, and the situation and form of the mouths of the cells are different. Moreover, the opercula and avicularia differ considerably, as will be seen by a reference to the figures. The lower part of the operculum is clouded with a close mottling, which is wanting in that of *C. fistulosa*, which is also smaller; and the avicularium is much wider, shallower, and sharper at the extremities.

As the opercula of the different species of *Cellaria* afford a valuable and easily applicable mode of discrimination, which has not hitherto been made use of, I have figured those of all with which I am acquainted, including the European *C. fistulosa* and *sinuosa*. In every case it is characteristic; and where there is the closest resemblance (*C. fistulosa* and *hirsuta* and *C. gracilis* and *tenuirostris*) the avicularia are totally distinct.

Family, TUBULIPORIDÆ.

Tubulipora concinna, n. sp. Plate I., fig. 10.

Zoarium nearly discoid, with a thin, smooth, or concentrically wrinkled lamina. Cells arranged in radiating, linear series, partially immersed in greater part of their extent, distinct and separated from each other, slightly contracted towards the orifice, which is produced into a long peristome; surface of cells with numerous white, prominent puncta, and frequently slightly rugose; intervening surface punctate in the same manner, or with white-bordered pores. Ovicells long, narrow inflations transverse to the rows of cells.

Port Phillip Heads, on shell and algæ; found also by Mr. J. B. Wilson.

This is a well-marked species, and shows the transition to *Diastopora*. The zoarium is discoid, but with the origin of the rows of cells in some specimens eccentric. One specimen shows a flabelliform arrangement, so that no doubt this is the primary form. The cells are arranged in more or less radiating series, separated from each other by the general surface of the zoarium. They are in great part subimmersed, but mostly free and turned forwards at the extremities, especially in the cells remote from the margin.

They are thickly punctate, and occasionally transversely rugose. The surface of the zoarium between the cells is glistening with numerous elevated white puncta or (from the perforation of these) white-bordered pores, frequently arranged in transverse curved rows, between which there are often also slight corrugations. The opening of the peristome is circular in the central cells and triangular in the marginal, the orifices of the cells being of the same shape. It differs from the other Victorian species, and is at the same time allied to *Diastopora* in the greater immersion of the cells, and in their separation by portions of the general surface of the zoarium.

Tubulipora pulchra, n. sp. Plate II., fig. 1.

Zoarium at first flabelliform, but becoming, by growth, of various forms. Cells in greater part decumbent and united to each other laterally, extremities free and more or less erect, narrowed towards the mouth, which is produced into a long, cylindrical peristome; surface thickly punctate, except the peristome, which is smooth, glossy, and usually annularly lined. Ovicells forming large inflations, elongated transversely to the direction of the cells. Colour, white.

Frequent on shells and algæ.

This species is closely related to the European *T. flabellaris,* of which it may prove to be a variety. It originates in the same manner by a single or multiple flabelliform growth, which ultimately assumes various forms, usually lobed at the margins. The cells are distinct throughout their whole length, for the greater part decumbent, and adhering to each other, but free and bent forwards towards the mouth. They are arranged in irregular, radiating or divergent lines, and are slightly contracted towards the mouth, which is nearly circular and produced into a long, nearly erect peristome. Their surface is glassy, thickly covered with round, raised white puncta, which, from the opening of the summits, usually appear as white-bordered pores. The surface of the cells is sometimes annularly rugose, and the mouth is occasionally closed by a punctate membrane. The ovicells are large, stretching across the lobules at the base or middle.

Tubulipora connata, n. sp. Plate II., fig. 2.

Zoarium originally flabelliform, becoming usually more or less lobed or discoid. Cells slender, arranged in radiating lines, adherent in greater part, but with the orifices upturned and produced into long peristomes which, as well as the cells, are mostly connate in each series. Surface of cells punctate as in the last species. Ovicells considerable inflations, parallel to the axis of the cells. Colour, bluish-purple.

Port Phillip Heads.

This species is at once distinguished by the peculiar arrangement of the cells and their peristomes. These are arranged in more or less perfect rows, radiating obliquely in the direction of the original lobules, those of each row being united in broken series quite to the orifices of the peristomes, so as to form wall-like rows. The number of cells united in each group varies from two to six or seven. The cells are, however, not all connate, many remaining single, and not being arranged in definite order, but the general arrangement is usually very marked and characteristic.

Tubulipora clavata, n. sp. Plate II., fig. 3.

Zoarium divided into clavate branches. Cells adherent or immersed, except at the extremities, which are free and turned forwards, arranged in oblique lines from the middle of the branch to the edges; surface punctate; mouth circular.

Port Phillip Heads. Dredged by Mr. Wilson and myself.

I have only seen one perfect specimen, for which I am indebted to Mr. Wilson. It consists of seven branches, united at their bases. The cells are closely packed, distinct but adherent, except at the extremities, which are free and turned forwards; they are punctate, with a circular mouth frequently produced into a short tubular peristome. They are arranged in nearly regular oblique lines from the middle of the branch to the edge, and each row has three to five at the narrow parts and six or seven at the expanded clavate portion; in many of the rows the cells are entirely connate. The front of each branch is considerably elevated.

Diastopora lineata, n. sp. Plate III., fig. 1.

Zoarium thick, adnate. Cells arranged in raised radiating rows, in single series at first, but at the extremities increasing to two or three. Intermediate surface and sides of rows finely punctate and transversely ridged.

Port Phillip Heads.

In this species the zoarium is thick, and surrounded by a lamina. The cells are arranged in radiating, prominent rows, from which they very slightly project. The central parts of the rows consist usually of only a single series, increasing towards the margin of the zoarium to two or three. In some specimens there are two series almost from the commencement. These series are in all cases continuous, and the ridges formed by them are considerably raised, sometimes much more so than in the specimen figured. The mouth is elliptical, and usually, except at the termination of the rows, closed by a punctate membrane. I have not seen any of the peculiar calyptriform covers on any of the cells, such as are found in *D. sarniensis.* The whole surface is thickly punctate, and the deep spaces between the ridges transversely rugose. It is readily distinguished by the great projection of the regular, radiating rows of cells.

Diastopora fasciculata, n. sp. Plate III., fig. 2.

Zoarium adnate, with a distinct lamina, partly free at the edges. Cells arranged in distinct, elevated, radiating ridges, very much enlarged and prominent at the extremities; the narrow parts very prominent, transversely wrinkled, and showing the mouths of a few closed cells, the extremities forming bundles of closely packed cells, mostly opening terminally. The surface between the ridges punctate and transversely rugose.

Port Phillip Heads, Mr. J. B. Wilson.

The only specimen I have seen is the one figured. The basis is a calcareous lamina, much twisted, probably from the nature of the object, seemingly a friable nodule, to which it was attached. The whole is irregularly divided into two lobes. The cells are arranged in distinct, radiating bundles, very prominent and narrow at their first portions, but becoming broader and partially free at their extremities. The narrow convex parts are transversely rugose, and the closed orifices of a few cells can be obscurely distinguished. The outer parts present the orifices of numerous, close-packed cells, opening in clusters or in a vertical single or double series.

Although entirely Diastoporidan, *D. fasciculata* shows a decided approach to the structure of *Fasciculipora* in the distinct bundles of cells opening at the extremities.

Family, DISCOPORELLIDÆ.

Favosipora, n. genus. Plate II., fig. 4.

Zoarium adherent, raised at intervals in irregular, elevated, rounded ridges, with a distinct lamina. Cells large, of unequal size, closely packed, prismatic.

F. rugosa, n. sp.

Forms small, crustaceous expansions, growing on a lamina like *Discoporella*. The zoarium is composed of large, closely set, prismatic cells. Their openings vary in shape, and also a good deal in size, but there is no structural difference between the largest and smallest. There are usually some irregular, elevated ridges, sometimes obscurely parallel, on different parts of the zoarium. In some cases the cells open all over these elevations, but frequently, especially in the higher, the sides are smooth, the cells opening only on the summit. Some of the cells are closed by a punctate or perforated calcareous membrane, confined to a single cell, or spreading over a number, as in the specimen figured. I cannot detect any spines in the interior of the cells.

This genus is evidently allied to *Densipora corrugata*, and there can be no doubt that they belong to the same family as *Discoporella*. On a fragment of stone I have two small, nearly discoid, specimens, which are forcibly suggestive of some forms of *D. radiata*.

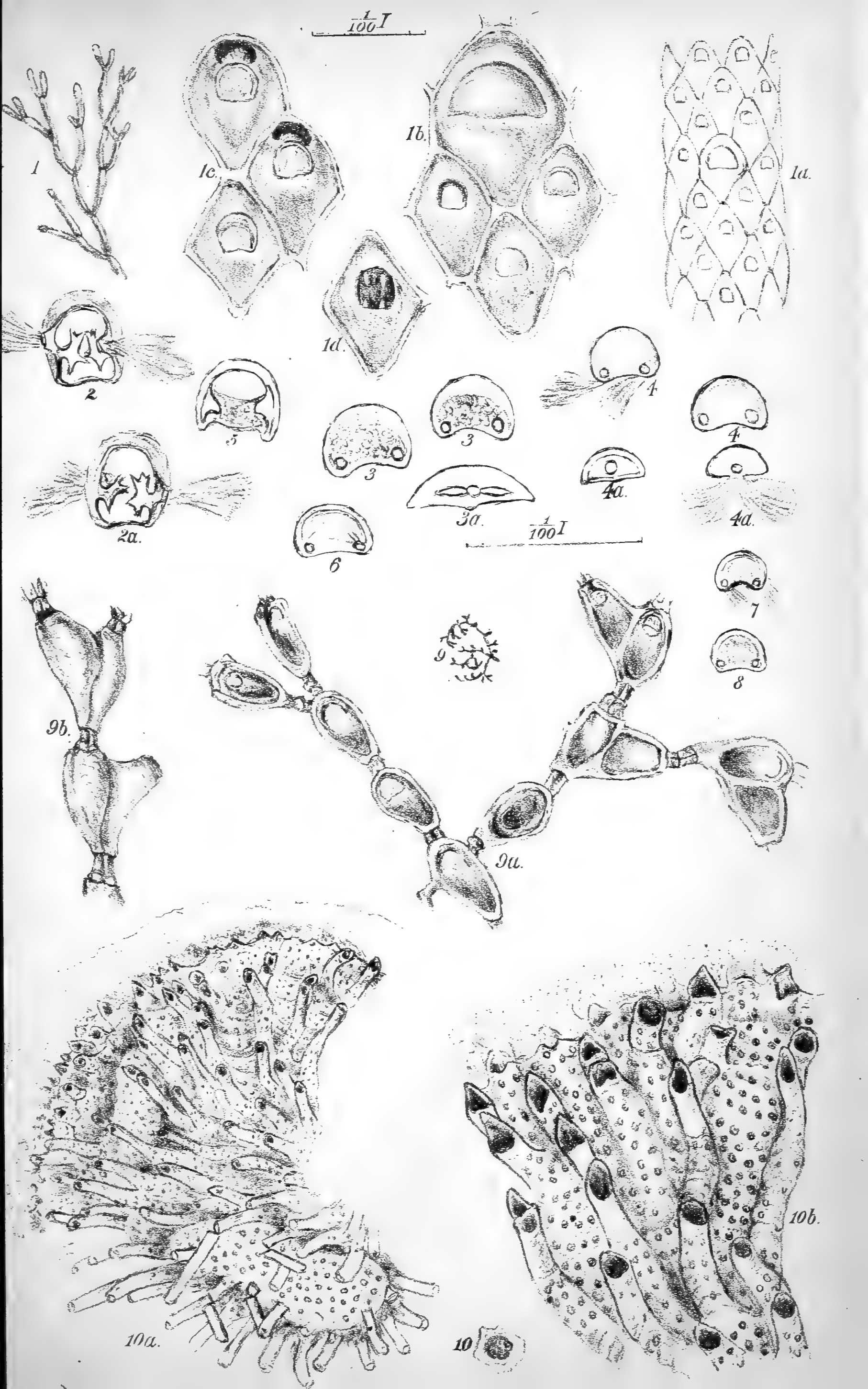
NOTE ON DIPLOPORA.

When I proposed the genus *Diplopora* for Mr. Hutton's *Membranipora cincta*, I was not aware that the name had already been used, and I would therefore now alter it to *Diploporella*.

EXPLANATION OF FIGURES.

PLATE I.

Fig. 1. *Cellaria rigida*, natural size. Fig. 1*a*. Portion of a branch, magnified. Fig. 1*b*. Group of cells and an avicularium, replacing a cell. Fig. 1*c*. Three cells, showing ovarian pores in two. Fig. 1*d*. Single cell, showing the intra-oral denticles.



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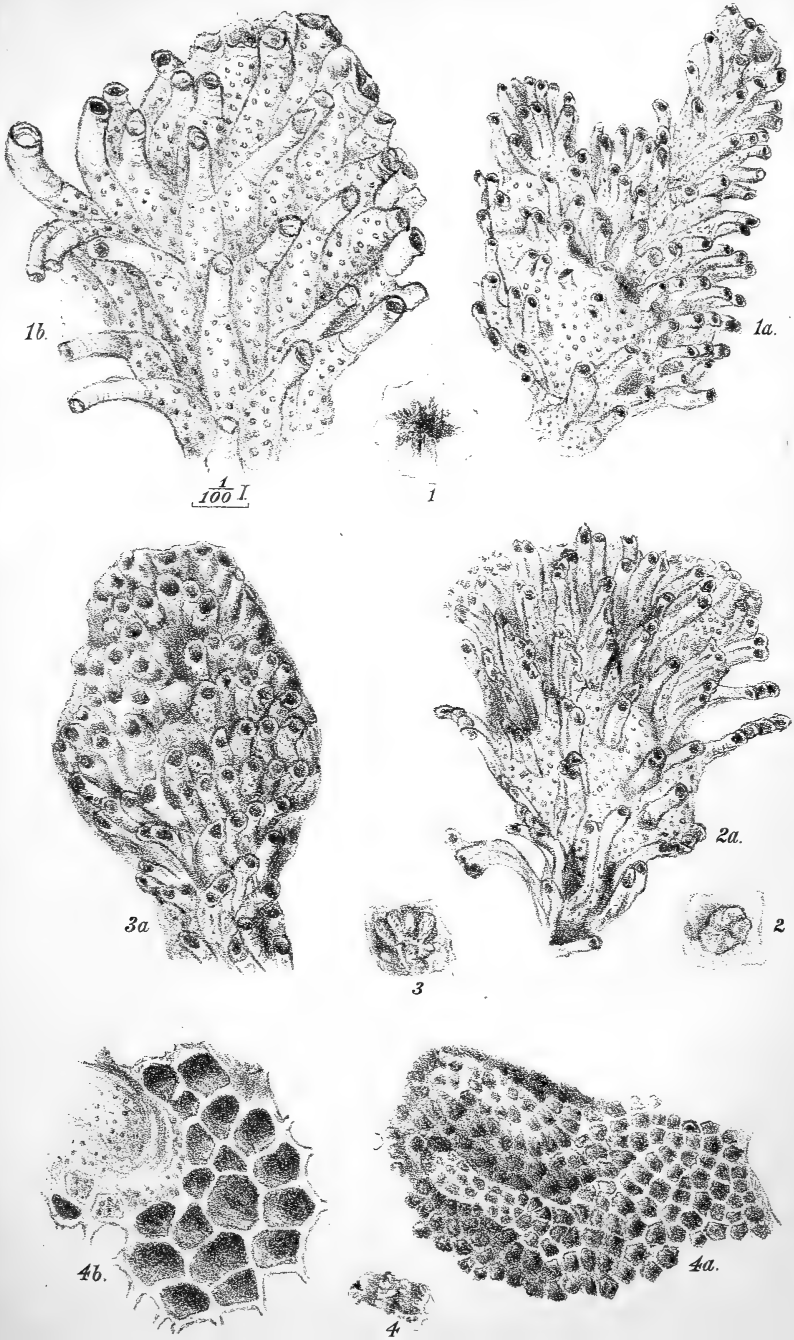
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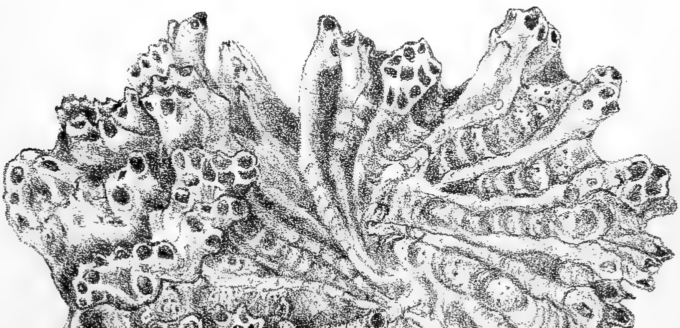

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Fig. 2. Operculum of *C. rigida*, posterior view, to show the attachment of the occlusor muscles. Fig. 2*a*. Anterior view of the same.

Fig. 3. Opercula of *C. Australis.* Fig. 3*a*. Avicularian mandible of the same.

Fig. 4. Opercula of *C. fistulosa*, from a Mediterranean specimen. Fig. 4*a*. Avicularian mandibles of the same.

Fig. 5. Operculum of *C. sinuosa*, from a Mediterranean specimen, showing processes for the attachment of the muscles.

Fig. 6. Operculum of *C. hirsuta.*

Fig. 7. Operculum of *C. tenuirostris.* It will be seen that the lower edge is more deeply hollowed than in the next.

Fig. 8. Operculum of *C. gracilis.*

Fig. 9. *Maplestonia cirrata*, natural size. Fig. 9*a*. Portion magnified, anterior view. Fig. 9*b*. Posterior view.

Fig. 10. *Tubulipora concinna*, natural size. Fig. 10*a*. Portion magnified, showing two ovicells. Fig. 10*b*. Portion more highly magnified.

Plate II.

Fig. 1. *Tubulipora pulchra*, natural size. Fig. 1*a*. Lobule magnified, showing an ovicell. Fig. 1*b*. Portion more highly magnified. The wrong scale has been accidentally placed to this figure; it should be the same as that in Plate I., fig. 10*b*.

Fig. 2. *Tubulipora connata*, natural size. Fig. 2*b*. Portion magnified.

Fig. 3. *Tubulipora clavata*, natural size. Fig. 3*a*. One of the branches magnified.

Fig. 4. *Favosipora rugosa*, natural size. Fig. 4*a*. Portion magnified. Fig. 4*b*. Small portion more highly magnified, showing the openings of the cells and the punctate calcareous membrane. The wrong scale has also been put to this figure; it should be the same as in Plate I., fig. 10*b*.

Plate III.

Fig. 1. *Diastopora lineata*, natural size and magnified.

Fig. 2. *D. fasciculata*, natural size and magnified. On the left of the magnified figure a portion of the lamina is shown.

Art. X.—*Fire Alarms.*

By Mr. R. E. Joseph.

[Read 10th July, 1884.]

Art. XI.—*Australian Cave Paintings.*

By Dr. S. M. Curl, of New Zealand.

[Read by the Secretary 14th August, 1884.]

Art. XII.—*An Inquiry into the Cause of Gravitation.*

By Mr. T. Wakelin.

[Read by the Secretary 14th August, 1884.]

Art. XIII.—*Supplementary Notes on the Diabase Rocks of the Buchan District.*

By A. W. Howitt, F.G.S.

[Read 16th October, 1884.]

On a former occasion I laid before the members of this Society a paper on the Diabase rocks of the Buchan district.* I was unable to speak at that time with desirable confidence as to the exact position and character of some of the formations which I found at Murendel South. Since then, however, I have taken occasion to carry out further examinations, and to collect materials for microscopic analysis of the rocks. The results are embodied in these notes and in the accompanying diagram section. I hope thereby to make my former account of the Upper Buchan beds somewhat more complete.

For convenience of treatment I have arranged my subject under the following sections:—

The Quartz Porphyrites.—The lowest rocks which I found at Murendel South are rough-textured, often massive, and always dark-coloured (red or purple) igneous rocks. In some places I have also observed just such rocks forming the higher ridges, and in such cases their position is probably due to the extensive faulting which has effected the district. In the diagram section I show rocks of this kind at the level of the Murendel River, and also at the summit of the ridge marked *(k)*.

The rocks at the place marked *(a)* and *(e)* are rudely bedded, and dip S. 30°—40° W. at about 15°. I prepared several thin slices of the samples I collected at *(a)* and *(e)*.

The ground-mass in these slices is crypto-crystalline, and is apparently composed altogether of minute granules of felspar and quartz, with some intermixed felsitic basis, which also fills in certain spots almost exclusively. In other places

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* Royal Society of Victoria, read 19th May, 1881.

the ground-mass becomes coarser in its elements, and the basis disappears.

In the ground-mass there are numerous fragments of quartz crystals, but these are "eroded," as is so frequently the case with quartz crystals in rocks of the quartz porphyry or quartz porphyrite classes, as, for instance, in those I have lately described from Noyang.*

I observed in some slices more than in others porphyritic felspars, as well as quartz crystals. These felspars have been so much altered that it is difficult to speak with absolute certainty as to what some of them have been. Some are converted into a saussurite-like compound, others are kaolinised and infiltrated by iron ore; but after a careful examination and comparison I have come to the conclusion that the majority of these porphyritic felspars were plagioclase.

I have not observed either mica or hornblende. The general red colour of these rocks is due to their being permeated by ferric hydrate, which is a secondary product.

According to the above definitions these rocks belong to the quartz porphyrites.

Somewhat to the north of the high point marked *(k)* in the diagram section, I have found an outcrop of rocks in one of the gullies leading to the Murendel River. The samples which I collected prove upon examination to belong to this section of my description. They are harsh textured rocks of a dark colour, inclining to grey or olive. They dip S. 10° W. at about 15°, and they appear to be bedded lavas, for I observed in them very numerous vesicles drawn out in a direction not quite that of the dip, indicating movements in the rocks when they took up their present positions. I found by the examination of thin slices that this rock has a ground-mass composed of quartz and felspar in variable proportions. In one part of a slice I also observed a mass of brown glassy basis enclosing portions of the micro-crystalline granular materials.

In this ground-mass there are very numerous quartz crystals, one of which is eroded and filled in by it in the characteristic manner. I found also several porphyritic crystals of felspar, in some of which I could observe the twin structure of the triclinic felspars. As a rule, these felspars are too much altered for their original

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* Royal Society of Victoria, read 10th May, 1883.

character to be seen. I have not observed any crystals of mica, or of hornblende, nor any alteration products which I could refer to those species, unless it were some slight traces of chloritic minerals.

This rock may, with some reasonable certainty, be referred to the quartz porphyrites, and I feel little doubt that it represents the former condition of the "red rocks" which I have just before described.

The Diabase Rocks.—Resting upon the red porphyrites there is a considerable thickness, perhaps 200 feet, of Diabase rocks. The lowest of these lies on the porphyrites, but I cannot feel sure that they are entirely conformable in dip to them.

The lowest Diabase rocks which I could examine are those indicated at *(d)*, and they are a good example of the Diabase tuffs of the district, containing also rounded fragments of the underlying red porphyrites. These tufas are so friable and so much altered that none of the samples I collected would admit of a thin slice being prepared for examination.

It is in a continuation of these fragmental beds that the adit of the now long-defunct Murendel South Mining Company was driven, at the place where the beds are cut off by a strong north and south nearly vertical fault, which I have shown on the diagram by *(x)*.

The heaps of stuff brought out of this adit during the time it was being worked show that the rocks adjoining the fault are much more altered than those at a little distance, and that they have been slightly enriched by deposits of lead and copper, and massed together by a good deal of red jasper and chalcedony.

The rest of the Diabase upwards from *(c)* consists of bands of various texture, some being fragmental and others compact. The latter show along the steep hill sides in several strongly marked outcrops.

I collected samples from the beds marked *(b)* and *(c)* and also at the place *(h)*.

On examining thin slices I found all to have the well-marked characters of the Diabase porphyrites, as described by me in the previous paper. All that I need note is that enstatite is rare, seemingly, as I found it only in one slice, and that the samples taken from *(c)* near the fault contain olivine. These samples are much altered, and the olivine is converted more or less into a translucent, red micaceous mineral (Rubellane), the final stage being to a hydrated ore of iron.* All these Diabase rocks belong to the same formation, and the same period of time as those I have described as occurring to the eastward of the Murendel River, and also at the Snowy River.

The Limestones.—On these Diabase rocks rest conformably about 150 to 200 feet of the Buchan limestones. I collected and examined examples from the places marked *(f)* and *(g)*.

These are all composed mainly of carbonates, whose yellow colour indicates the presence of iron among their bases. The carbonates are confusedly aggregated together as masses of rhombic crystals, including numerous angular fragments of quartz crystals, and of pieces of more or less altered porphyrite rocks. Here and there spaces are filled in by choritic minerals.

These limestones, without doubt, represent the passage beds which I have before described as connecting the upper and lower divisions of the Buchan beds.

The Faults.—The group of formations which I have now briefly described are cut off on the western side by a double fault shown upon the diagram section as (x)—(x^1). The eastern fault of the two is, I suspect, a continuation of that on which the workings of the Murendel Mine have been carried on.

Such faults as these seem to be common in the district. Perhaps to speak more correctly, I might say that such faults are more easily recognised in the Buchan district, where the succeeding formations differ so much from each other than in other parts of North Gippsland, where are found only the Silurian series, and the igneous rocks which have intruded into it.

The faults at Murendel seem to me to have an essential relation to the ore deposits. In their neighbourhood the rocks of whatever kind are seen to have been more or less altered. The quartz porphyrites have been least affected; the Diabase rocks most so; and the limestones have, as a rule, been bleached and crystallised. All the rocks traversed by these faults near Murendel have been more or less impregnated with ores of various metals, and in certain places the deposits of ore have been such as to induce mining companies to attempt working them.

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* See *Progress Report, No. 5, Geological Survey of Victoria*, p. 143.

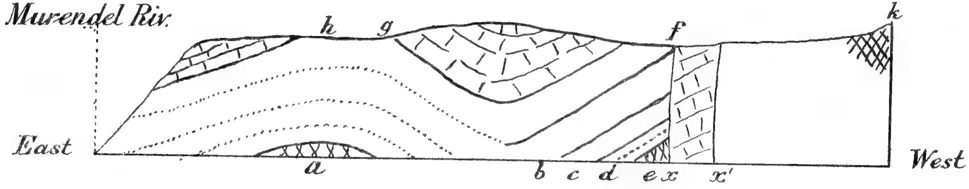

Diagram Section at Murendel South

Approximate Scale, 500 f^{t} to one Inch

As to the period at which these faults were formed, I cannot well form an opinion beyond this: that they are subsequent in age to the Middle Devonian, for they pass through the Buchan beds, which, in the locality referred to, terminate the geological record.*

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* In the *Report of Progress, No. 5, of the Geological Survey of Victoria*, p. 134, I suggested an explanation of the formation of the ore deposits at Murendel. At that time I inclined to the belief that the black basalt-like rocks at Back Creek might be intrusive. Subsequent investigations have shown that these rocks belong to the Diabase porphyrites, and are contemporaneously interbedded in the Buchan series. It is therefore necessary to point out that in so far my suggestion requires to be modified, but it may remain as to the probable reactions between metallic solutions permeating the faults and the organic constituents of the limestones which they traversed.

Art. XIV.—*Descriptions of New, or Little Known, Polyzoa.*

Part VIII.

By P. H. MacGillivray, M.R.C.S., F.L.S.

[Read 20th November, 1884.]

Family Catenicellidæ.

Catenicella gracilenta, n. sp. Plate I., fig. 3.

Cells much elongated, very narrow; mouth arched above, slightly hollowed below, or subcircular. Anterior surface papillose; posterior, smooth. A narrow, entirely lateral vitta extending the whole length of the cell. Lateral processes small, usually with a sharp angle above projecting outwards and forwards; a minute avicularium opening outwards on the outer edge. Ovicell cemented to the front of the cell above, which is sessile on the ovicelligerous cell, with a quadrate smooth area.

Port Phillip Heads, dredged by Mr. J. B. Wilson and myself.

This is a small species, readily distinguished by its exceedingly slender cells. The ovicell is peculiar. As in *C. elegans, Buskii, fusca,* and some others, it is cemented to the front of the cell above, which is sessile on the ovicelligerous cell. On the front of the ovicell is a quadrate, smooth area, about twice as high as broad, totally different from the marking of any other species. I had, unfortunately, not seen the ovicell before the plate was lithographed, so that it is not figured. The specific name was suggested by Mr. Wilson.

We have several other forms of *Catenicella*, which I believe to be different from those described. The discrimination of the minute species is not always easy, and the whole genus requires a careful revision, which I hope to be soon able to make.

Family CELLULARIIDÆ.

Canda tenuis, n. sp. Plate IV., fig. 1.

Zoarium very slender; cells biserial, elongated; a spine on each side above; margins thick and crenulated; aperture elliptical, occupying about two-thirds of the front; avicularia on the median tract large, with the mandible opening upwards; vibracula with groove extending beyond the cell and encroaching on that of the opposite series; setæ slender, smooth; radical connecting tubes slender.

Port Phillip Heads.

This is closely allied to the common *C. arachnoides*, from which it is distinguished by its much smaller size, more slender branches, and especially by the vibracular grooves for the lodgment of the setæ extending on the surface of the cell on the other series; while in *C. arachnoides* they are confined to the cells to which they belong, not reaching quite to their inner edges.

Maplestonia simplex, n. sp. Plate I., fig. 2.

Zoarium formed of slender, dichotomously-divided branches, each division rising from the outer angle of a cell, and each internode being unicellular. Cells elongated, expanded above, narrowed below; margin thickened and inflected; the anterior surface filled in by a thin membrane, with the mouth opening by a flap at the upper extremity. Posterior surface smooth.

Port Phillip Heads, Mr. J. B. Wilson.

Forms small tufts, about three-quarters of an inch in height, of slender dichotomously-divided branches. The cells are elongated, wide and square above, tapering below, and each gives rise to another at each upper angle, so that the internodes are unicellular. The joints are annulated.

Family SALICORNARIIDÆ.

Tubucellaria cereoides, Ellis and Sol. Plate I., fig. 4.

Zoarium consisting of cylindrical branches, each branch articulated by a corneous tube to the side of that from which it springs. Cells indistinct; mouth circular; peristome slightly projecting; whole surface punctate.

Port Phillip Heads, Mr. J. B. Wilson.

Of this I have only seen two specimens, sent to me by Mr. J. B. Wilson; one three-quarters of an inch in length, the other smaller. The zoarium consists of cylinders branched exactly as in *Cellaria australis*, the branches not dviding dichotomously, but rising from the sides by flexible corneous tubes. The cells are, on the surface, quite confluent, and mostly only distinguishable by their mouths. The whole surface is beautifully punctate, the punctations being caused by the reticulation of chains of small depressions or pores. The cells are slightly bulging below, and there is usually a minute circular opening above the middle, not shown in the figure.

In a Mediterranean specimen, the cylinders present the same appearance, but are more calcified, and some are larger. The chains of reticulation are raised by calcareous deposition, so as to leave pits corresponding to the punctations in the Victorian specimen figured. The cells are more bulging, mostly separated by distinct lines, and the peristome is more prominent. The corneous tubes connecting the smaller tubes are annulated. The connection of some of the larger cylinders is composed of bundles of tubes similar to the radical tubes, by a mass of which the whole zoarium has been attached. The latter, however, are very loose, branched and jointed.

Family BICELLARIIDÆ.

Beania Wilsoni, n. sp. Plate II., fig. 1.

Cells connected with six others by long, corneous tubes, suberect, entirely open in front; two or three short, straight, slender spines, and one or two sharp, incurved spines on the margin on each side. Posterior surface smooth. A large, capitate avicularium articulated at the upper part of the cell on each side.

Port Phillip Heads, Mr. J. B. Wilson.

This is undoubtedly distinct from the other Australian forms described, although in some respects approaching *B.* (*Diachoris*) *spinigera*. It is, however, closely allied to the South African *Diachoris distans* of Hincks, from which it differs in having avicularia on both sides, and in the absence of the round mark of the radical tube posteriorly.

Another species of *Beania*, which has been dredged at the Heads by Mr. Wilson and myself, seems to be identical with Busk's *D. costata*, described from Kerguelen's Land (*Phil.*

Trans. 1879, extra vol.), from which it differs only slightly in the size and direction of the avicularia, which in the Kerguelen form are described as large and reclinate, and seem to be very similar to those of *B. spinigera,* while in the Victorian specimens they are smaller, and pointed more forwards.

I have already given my reasons for uniting most of the species of *Diachoris* with *Beania,* and referring the others elsewhere.

Family GEMELLARIIDÆ.

Urceolipora dentata, n. sp. Plate I., fig. 1.

Cells arranged in a double series facing opposite ways, alternate, elongated, subcylindrical, but narrowed below and projecting in front. Mouth terminal, oblique, lower margin straight, upper semicircular with usually five short, stiff spines. Ovicell large, imbedded in the front of the cell above.

Port Phillip Heads, dredged by Mr. Wilson and myself. Forms small tufts about an inch high. The cells bear a marked resemblance to those of *Calwellia bicornis,* although there is not the same peculiar mode of connection. On the lower lip there is on each side a minute mark or pit, and immediately below a small median pore.

Family FLUSTRIDÆ.

Cabasea reticulum, Hincks. Plate IV., fig. 2.

I have received some small fragments from Mr. Wilson which seem referable to the *Flustra reticulum* of Hincks (*Ann. and Mag. Nat. Hist., Aug., 1882*). The zoarium is divided into broad, short, ligulate branches. The cells, which are disposed in a single layer, are of large size, rounded above, wider at the middle, and contracted below. The margins are very prominent, and the mouth is small, situated at the upper part.

In one of the specimens a cell is surmounted by an ovicell, which is rounded, extending about half way up the cell above. In the same specimen there is a single avicularium which agrees with Hincks' description, and is very peculiar. It replaces a cell and is of the same size. The mandible is very large, rounded above, and convex, fitting closely to the thin margin. The lower part of the avicularian cell, below the articulation of the mandible, is very small, membranous, and triangular. The specimens present an extraordinary development of spines. These are situated along the posterior edges of the zoarium, are directed upwards, backwards, and inwards, and are divided into numerous long, nearly straight, sharp branches. They are not noticed by Hincks, and as the specimens agree with his figure and description in other respects, I think they can only be varietal, and cannot consider them as of specific value.

Family MEMBRANIPORIDÆ.

Membranipora bimamillata, n. sp. Plate II., fig. 2.

Zoarium encrusting. Cells elongated, quadrate, separated by raised margins. Aperture elliptical, the edge formed by a thickened, crenulated rim; the lower part of the aperture occupied by a large plate or denticle, sloping backwards and usually with a fissure or notch on one side. Front of the cell formed by a calcareous, granulated lamina, sloping inwards to the aperture. At the lower part of the cell are two rounded prominences or mamillæ, or occasionally only a single, transversely elongated mass.

Portland, Mr. Maplestone.

The broad, smooth plate at the lower part of the aperture is evidently of the same nature as the serrated denticle of *Biflustra delicatula*, with which, and *M. papulifera*, this species is closely related.

Membranipora porcellana, n. sp. Plate II., fig. 3.

Cells small, quadrate, separated by distinct, narrow, raised margins; upper part membranous; lower part occupied by a large, smooth, white elevation; a short, thick, rounded process on each side at the upper angle.

Portland, Mr. Maplestone.

The cells in this species are very peculiar. They are quadrate, separated by narrow, raised margins. The upper half is membranous, the membranous front being situated at a considerable depth, with the flap-shaped mouth at the upper end. The lower half is prominent, smooth, white, calcareous, rising higher than the separating margin. The upper part of the cell is in the form of a broad, shallow arch hollowed out in the base of the prominent portion of the cell above.

Family MICROPORELLIDÆ.

Microporella scandens, n. sp. Plate IV., fig. 7.
Alysidota ciliata, M'G.

In 1869 I described a form which I referred to Busk's genus *Alysidota* as *A. ciliata.* I am, however, satisfied that *Alysidota* is founded on insufficient characters, and that this species is rightly referred to *Microporella*, one of the commonest species of which is the well-known *M. ciliata*, so that it is necessary to give it a new specific name. I have only seen one specimen, which consists of a chain of eight cells, four surmounted by ovicells, running up a branch of *Bicellaria grandis.* The cells are pyriform. The mouth is arched above and straight below. There are four or six long, articulated oral spines. The surface is smooth, and presents no marks except the suboral pore, which is small and semilunar. The ovicell is of large size, rounded, and the upper edge, where attached to the cell above, is slightly dentate in the same manner, but not so distinctly as occurs in *M. Malusii.*

Microporella diadema, M'G. Plate IV., figs. 3—6.

This beautiful species varies considerably in the appearance of the surface of the cell and ovicell, according to the amount of calcareous deposit, in the size of the spines, the form and size of the suboral pore, and the situation and direction of the avicularia. In fact, it is even more variable than its well-known congener, *M. ciliata.*

In the typical form the surface is only slightly calcareous, smooth or with a few impressions round the margin. The suboral pore is not more than a third part of the width of the mouth, and is rounded or semicircular. The avicularia are situated on one or both sides on a level with, or rather above, the pore, and are directed outwards and slightly downwards. The front of the ovicell is smooth, surrounded by a prominent broad band of radiating beaded ridges.

The following varieties, which I have figured, seem worthy of distinction:—

Var. *lunipuncta.*—In this variety the cells are broad, smooth, and slightly grooved at the edges. The suboral pore is a narrow, lunate slit, equalling the mouth in width. The avicularia are of large size, situated below the pore, and with the mandibles pointed outwards and upwards. The ovicell presents the usual arrangement, but is flatter.

Var. *longispina.*—Cells broad, smooth, flat, and slightly calcareous, grooved at the edges. The spines round the mouth are very large and long, articulated and jointed; the lower, on one or both sides, of enormous length, and divided by two or three corneous joints. Suboral pore round, oval, or semicircular; about the same width as in the normal form. Avicularia large, opposite the pore, and pointing downwards and outwards.

Var. *lata.*—Cells broad, flat, smooth, except some faint grooving at the edges. Pore of moderate size, semilunar. Usually an avicularium on one side only, although occasionally on both; generally situated above the level of the pore, sometimes by the side of the mouth, the long slender mandible directed mostly downwards, with a slight inclination outwards, but at other times directed more outwards.

Var. *canaliculata.*—I have had some doubt about this form, but am satisfied, after an examination of specimens in various stages, that it is merely a variety of *M. diadema*, the differences being caused by a large deposition of calcareous matter. The edges of the cells are deeply grooved, the intervening walls, as well as the cell margin, very calcareous. A mass of calcareous matter is heaped up in a sort of semilunar ridge in the middle of the cell. The suboral pore is of moderate size, round. There is a large avicularium on one side, on the level of the pore, the mandible directed straight outwards. In the ovicell the beaded band has become smooth, and from its inner edge a series of deep grooves, with calcareous intervening ridges, radiate inwards to the centre, which is elevated into a calcareous mound.

Family MYRIOZOIDÆ.

Schizoporella cryptostoma, n. sp. Plate II., fig. 4.

Cells indistinct. Mouth arched above, straight below, with a large sinus. 4—6 articulated spines on the margin, the lower, on one or both sides, frequently larger. A large, conical process arising from the centre of the lower margin of the peristome, and almost entirely concealing the oral sinus. Surface of cells tubercular and glistening. Ovicell large, rounded, prominent, shining, surface smooth, or with faint, converging lines. Avicularia of two kinds, either small, broad, and situated on a calcareous eminence, usually by the side of the mouth, or of great size, with a long, narrow, acute mandible, nearly equalling the cell in length.

Port Phillip Heads, Mr. J. B. Wilson.

At first sight this species has a striking resemblance to a *Rhyncopora,* especially *R. longirostris* of Hincks, the large avicularia of which are very similar. The formation of the oral process, however, is quite distinct. It is not an outgrowth from the side of the mouth, but is a process of the peristome springing from the lower margin below the sinus.

Family CELLEPORIDÆ.

Lekythopora hystrix, M'G. Plate II., fig. 6.

Of this species I have given an illustration to show the form of the mouth, which, in my previous figures, was obscured by the growth of the peristome. It is lofty, and with a sinus in the lower lip.

Cellepora munita, n. sp. Plate II., fig 5.

Zoarium erect, branched ; branches cylindrical, annulated by slight depressions surrounding the branches. Cells confused, indistinct. Mouth wide, with a deep rounded sinus below. An avicularium on one or both sides. Numerous scattered avicularia of varying size, some very large. Ovicell with a distinct area, with numerous small depressions.

Port Phillip Heads, dredged by Mr. Wilson and myself. Readily recognised from our other Victorian species by the distinctly annular appearance of the thick, blunt branches.

Cellepora longirostris, n. sp. Plate III., fig. 1.

Zoarium erect, branched, cylindrical. Cells very indistinct, decumbent. Mouth with a distinct, rounded sinus. A small avicularium is found on one side of the sinus, becoming carried forward by the development of the peristome, the opposite corners of which arch over in front of the sinus, meeting to form a rounded opening, which afterwards is filled in. Numerous scattered avicularia, with very long, narrow mandibles, pointed downwards.

Port Phillip Heads, Mr. J. B. Wilson and myself.

Cellepora platalea, M'G. Plate III., fig. 2.

This species has been already described (*Trans. Roy. Soc., Vict.*, 1869), but not figured.

Zoarium very small, glassy, encrusting. Cells very small, rounded, irregularly heaped. Mouth slightly hollowed below, but without a distinct sinus; frequently a broad, suboral mucro. Avicularia with very long, slender, spatulate mandibles. Ovicells globular, with a distinct arched area, with radiating grooves.

A very minute and probably common species, distinguished by the markings on the area of the ovicell, and the long, very narrow spatulate avicularia. The figure is not quite correctly lithographed, the lower lip of the mouth showing a sinus instead of a slight hollow.

Cellepora Costazii, Aud. Plate III., fig. 3.

Zoarium encrusting. Cells ovate, smooth, irregularly arranged, confused. Mouth wide, with a broad, rounded sinus in the lower lip. Usually a prominent mucro below the mouth supporting a small avicularium, and occasionally an aviculiferous process from the peristome on one or both sides. Numerous scattered avicularia, some very large, with broadly expanded spatulate mandibles. Ovicells of moderate size, with a rounded or mitriform area, bounded by a distinct raised margin, pitted or sculptured in a radiate manner.

Port Phillip Heads, probably common.

There can be no doubt of the identity of this with the European species (described also as *C. Hassallii*). The only difference I can see in Australian specimens is that the spatulate avicularia attain a considerably larger size.

Cellepora serratirostris, n. sp. Plate III., fig. 4.

Zoarium encrusting. Cells much confused, granulated; the outer, towards the growing edge, decumbent, elongated, the older more erect, stouter, and thicker, Primary mouth with a deep sinus, which becomes bridged across or closed by the junction of the opposite angles. A suboral process, usually bending to one side, with a large avicularium at the summit. Avicularia very numerous, and of various forms, thickly scattered over the zoarium; some very large, with long, spatulate, blunt or pointed mandibles, raised on considerable boat-like elevations; some spatulate and smaller; some on rounded cells, with broad mandibles, the upper edge of the rostrum serrated.

Port Phillip Heads.

The most marked peculiarity of this species is the great abundance and extraordinary forms of the avicularia. The marginal cells are elongated and decumbent; the very youngest have the mouth straight and entire below, but in almost all a process of the peristome is seen rising on each side and meeting in the centre, leaving a round opening (Fig. 4*c*), which in time becomes filled in. Below the mouth a process rises on one side, extending upwards and curving over to the opposite side, with a considerable avicularium on its summit, the top of the process, where the mandible shuts down, being serrated. In some marginal cells this process is very large and directed upwards (4*a*), the avicularium situated obliquely on the summit. In some (4*c*) it is much smaller. The older cells vary much in shape, being usually short and oblique, or nearly erect. The oral pore of the peristome can frequently still be seen, and the peristome is also in some cases produced above in a hooded manner somewhat like a commencing ovicell. In one or two the peristome is almost tubular, with a slit in the lower edge. The aviculiferous process below the mouth is usually of small size. Besides, the avicularium on this process, there is a multitude of others scattered over the zoarium. Some are small and spatulate, others of the same shape but of enormous size and much raised, the point of the calcareous eminence projecting over part of the neighbouring cells. Others are broad and thick, almost globular, either separate or taking the place of the suboral process, with broad mandibles, the upper receiving edge of the cell or rostrum being serrated. Besides these, there are a few of great size, projecting above the surface of the zoarium, with very large broad mandibles and the upper edge serrated (Fig. 4*d*). The whole surface of the cells and avicularian cells is finely granular.

Cellepora megasoma, M'G. Plate III., fig. 5.

Zoarium encrusting. Cells ovoid, irregularly arranged, frequently bulging below, and with an imperfect umbo. Mouth arched above, about as high as wide, with a rather sharp sinus in the lower lip. Scattered avicularia, frequently a small one, with a semicircular mandible below or to one side of the mouth. Ovicell not prominent, granular, or pitted.

Port Phillip Heads.

Forms a large, encrusting zoarium, one specimen measuring 2 inches by 1½ inches. The marginal cells, as usual in the *Celleporæ*, are decumbent, and I believe it was a cluster of these that I described previously as *Lepralia megasoma*. The others are elevated in various degrees. There is no distinct mucro. The surface of the cells is normally smooth, but in portion of one specimen, in which most are so, a number have a series of longitudinal, elevated ribs extending the whole length. The markings on the ovicells are convex, but become worn off, and then appear as pits. It forms a transition between the genera *Schizoporella* and *Cellepora*.

Cellepora rota, n. sp. Plate III., fig. 6.

Zoarium encrusting. Cells irregularly arranged, nearly erect, more or less globose. Mouth with a deep sinus in the lower lip; an elevated process, surmounted by a short, broad avicularium on each side, the mandible broadly triangular, with an obtuse point; surface smooth or pitted. Ovicells much raised, with a nearly circular, defined area, marked by radiating grooves.

Port Phillip Heads.

The cells are very distinct, the old ones nearly globular, and looking directly upwards. The peristome forms a narrow rim with a prominence on each side, on the summit of which is a short, broad avicularium, with the mandible pointed upwards and outwards. My specimens have no avicularia except those at the sides of the mouth.

Family TUBULIPORIDÆ.

Tubulipora lucida, n. sp. Plate V., fig. 1.

Zoarium small, flabelliform. Cells mostly distinct, arranged in irregular rows, smooth and glistening; peristome long, tubular, white, with a nearly circular mouth. Ovicells large inflations, pierced by numerous cells, thickly covered with white-bordered pores.

Port Phillip Heads; Portland, Mr. Maplestone.

I have seen several specimens of this species, the most perfect being that figured, which was found at Portland by

Mr. Maplestone. It is distinguished by the polished, glistening surface of the cells, usually destitute of any marks, but occasionally showing a few small puncta. Sometimes a few cells in a series are united side to side, and in that case the orifices of the peristome are somewhat prismatic.

Diastopora bicolor, n. sp. Plate V., fig. 2.

Zoarium nearly circular, consisting of three parts: a central elevated portion composed of perfect cells, surrounded by a broad fringe of imperfectly developed cells, beyond which is a thin lamina; the central portion is red, the remainder glassy. The central portion is much raised, flat and depressed at the centre. The cells are arranged in irregular, radiating series; the series are distinct, but without intervening spaces. The cells are slightly rugose and thickly punctate. The mouth is oval or elliptical, with slightly thickened margin; those of the marginal cells are open, most of the inner being filled in by a plate punctate or perforated like the rest of the cell. In the central part are numerous rounded eminences, mostly at the commencement of the series of cells, and of the same width; they are punctate or perforated in the same manner, but present no trace of mouth. The surrounding fringe consists of a broad layer of imperfectly developed cells; the thin lamina beyond this is marked with slight, radiating grooves, as occurs in the corresponding part of other species of *Diastopora* and *Discoporella.*

Port Phillip Heads, Mr. J. B. Wilson.

EXPLANATION OF FIGURES.

Plate I.

Fig. 1. *Urceolipora nana.* Fig. 1*a.* Two cells more highly magnified. Fig. 1*b.* Portion of branch showing two ovicells, from a specimen mounted in balsam, and seen by transmitted light.

Fig. 2. *Maplestonia simplex,* natural size. Figs. 2*a* and 2*b.* Front and back views of portion of the same.

Fig. 3. *Catenicella gracilenta.* Fig. 3*a.* Back view of the same.

Fig. 4. *Tubucellaria cereoides,* natural size. Fig. 4*a.* Portion of the same magnified.

Plate II.

Fig. 1. *Beania Wilsoni,* front view. Fig. 1*a.* Back view of single cell.

Fig. 2. *Membranipora bimamillata.*

Fig. 3. *Membranipora porcellana.* Fig. 3*a.* Portion of the same more highly magnified. The wrong scale has been accidentally given; the enlargement is about twice that of the other figures.

Fig. 4. *Schizoporella cryptostoma,* portion near the edge of the zoarium. Fig. 4*a.* Group of cells from the same specimen, showing ovicells and avicularia.

Fig. 5. *Cellepora munita,* natural size. Figs. 5*a* and 5*b.* Portions magnified. Fig. 5*c.* Operculum, more highly magnified.

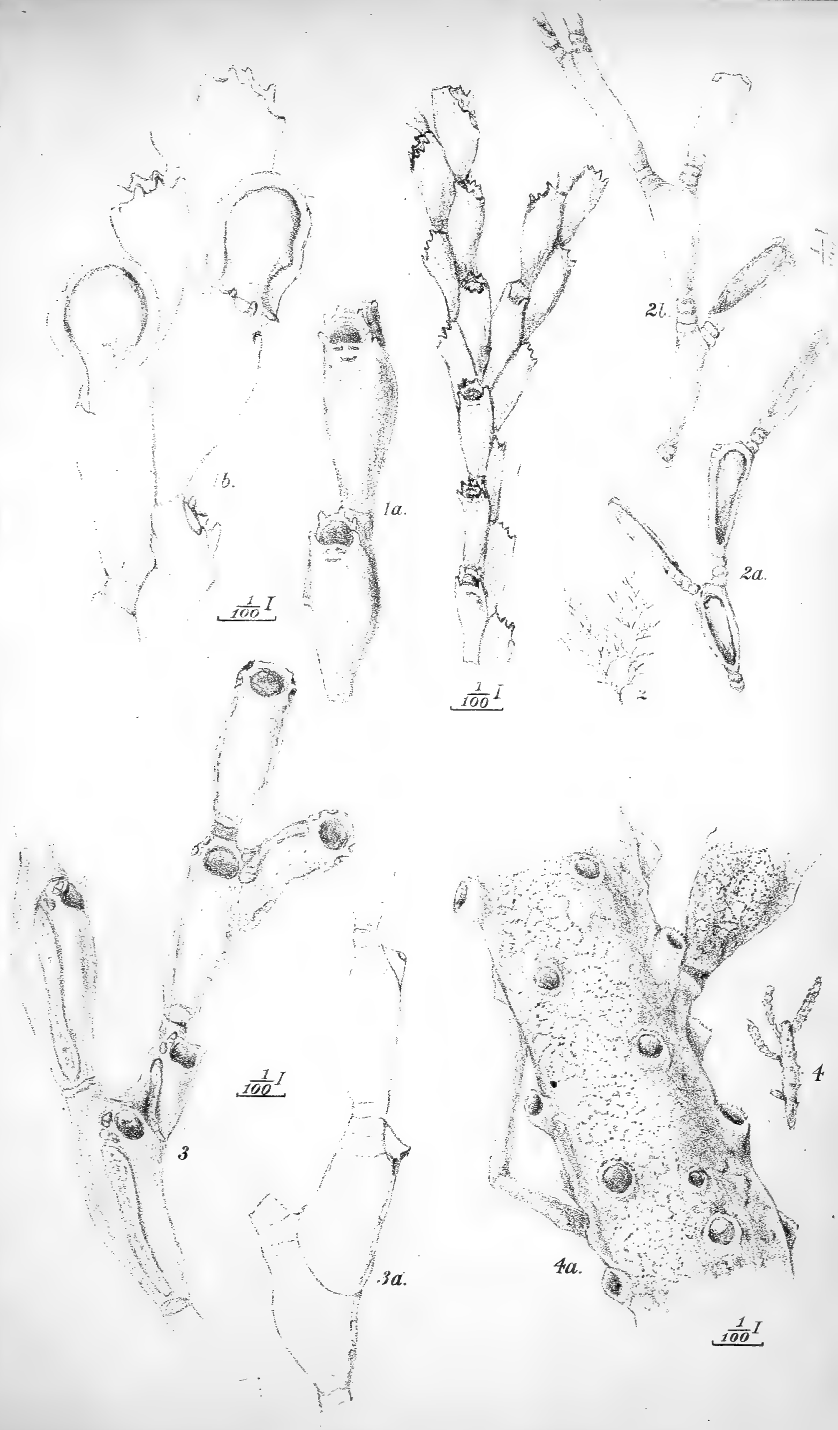
Fig. 6. *Lekythopora hystrix,* to show the form of the primary mouth. Fig. 6*a.* Operculum.

Plate III.

Fig. 1. *Cellepora longirostris,* natural size. Fig. 1*a.* Portion magnified.

Fig. 2. *Cellepora platalea,* group from the growing edge. Fig. 2*a.* Group of old cells, showing the avicularium and ovicells. There is too marked a sinus in the lower lips of the cells, which should be nearly straight or slightly hollowed.

Fig. 3. *Cellepora Costazii.* Fig. 3*a.* Ovicells of same. Fig. 3*b.* Single cell, with small avicularium on high process.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1a.
1
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4b.
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3a.
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5
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5b.
5c.
6
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2a.
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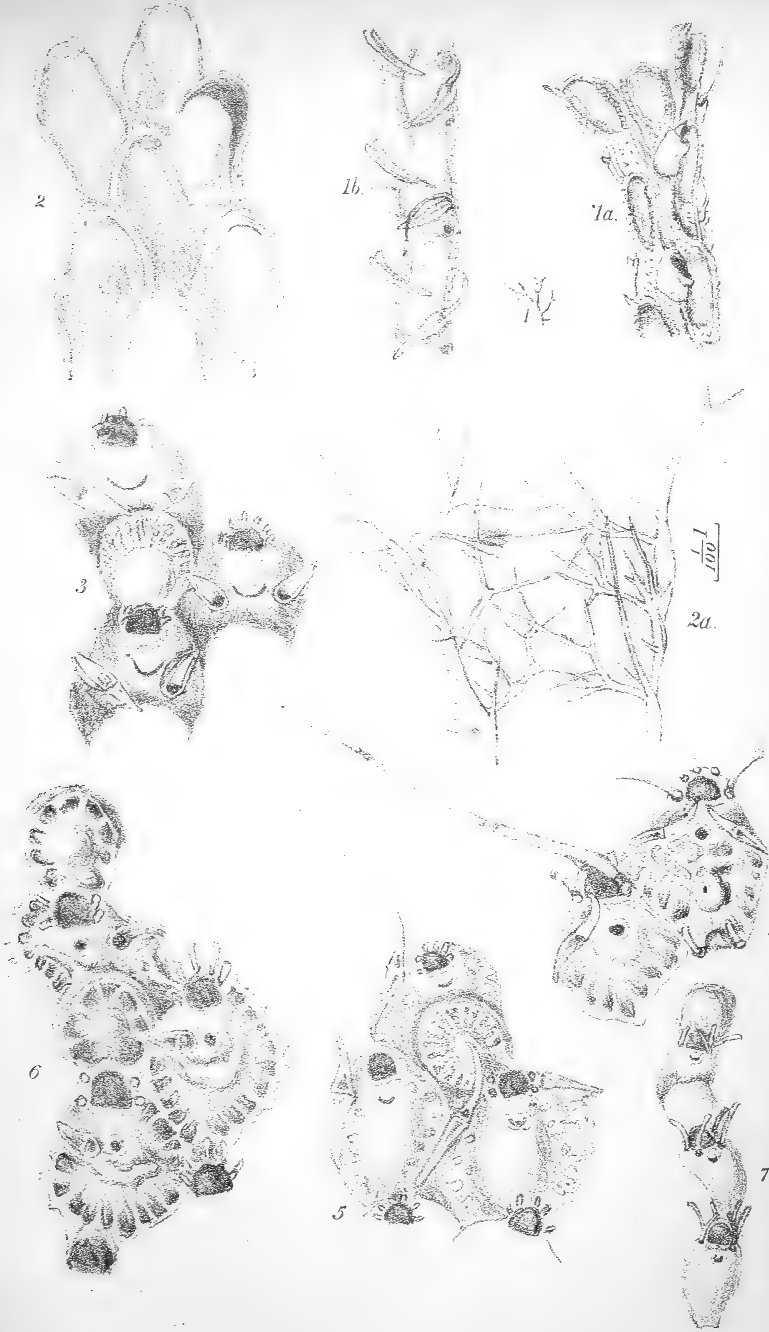

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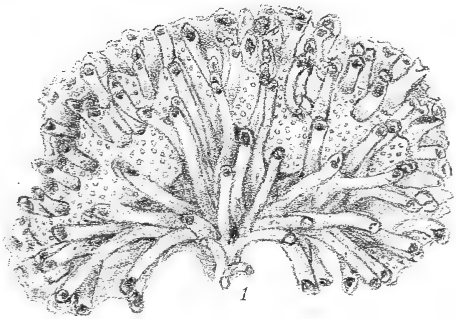
Plate V.



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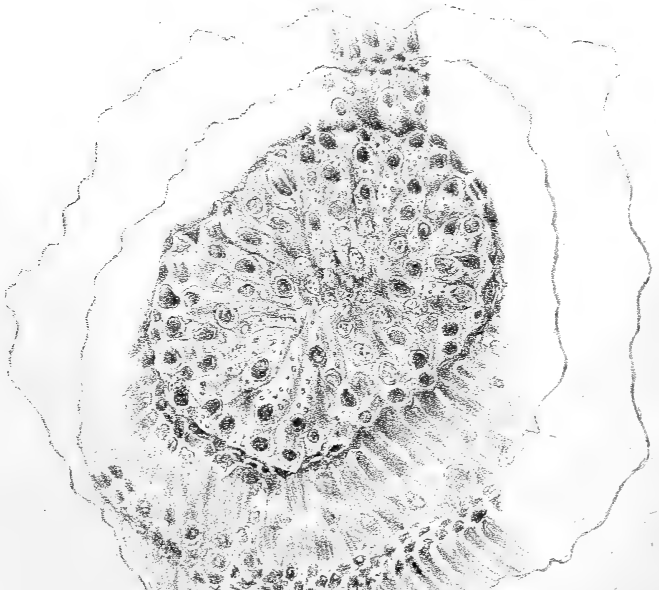

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Fig. 4. *Cellepora serratirostris*, natural size. Fig. 4*a*. A group of cells from the edge of the zoarium. Fig. 4*b*. Group of older cells. Fig. 4*c*. Single cell, showing the pore formed by the growth of the peristome, and a short aviculiferous process. Fig. 4*d*. One of the peculiar large avicularia, with broad mandible.

Fig. 5. *Cellepora megasoma*. Fig. 5*a*. Group of cells showing ovicells and avicularia. Fig. 5*b*. Small group more highly magnified.

Fig. 6. *Cellepora rota*, two young cells. Fig. 6*a*. Older cells and ovicells. Fig. 6*b*. Vertical view of single cell, showing the form of the mouth.

Plate IV.

Fig. 1. *Canda tenuis*, natural size. Figs. 1*a* and 1*b*. Anterior and posterior views of the same magnified.

Fig. 2. *Carbasea reticulum*, anterior view of cells, showing also an avicularium. Fig. 2*a*. Posterior view to show the large branched spines, not so much magnified. The outlines of the cells are not shown, as they were obscured with mud.

Fig. 3. *Microporella diadema*, var. *lunipuncta*.

Fig. 4. *Microporella diadema*, var. *longispina*.

Fig. 5. *Microporella diadema*, var. *lata*.

Fig. 6. *Microporella diadema*, var. *canaliculata*.

Fig. 7. *Microporella scandens*.

Plate V.

Fig. 1. *Tubulipora lucida*.

Fig. 2. *Diastopora bicolor*.

Art. XV.—*Note on the Reproduction of the Ornithorhynchus.*

By P. H. MacGillivray, M.A., M.R.C.S., F.L.S., *President of the Bendigo School of Mines Science Society.*

[Read 20th November, 1884.]

The Bendigo Science Society having offered a reward for female specimens of Ornithorhynchus, procured in the end of October or beginning of November, several have been forwarded, a brief notice of the examination of which may be of interest. The specimens were five in number. Of these, two contained ova, two had given birth to the young or ova, and one was unimpregnated.

Of the first specimen I received only the left uterus and ovary, which had been removed and were sent to me by Mr. Long, of Elmore. It was shot on 1st October. In the ovary I found two ruptured ovisacs. One was much projecting, with a conical or mamilliform point, at the summit of which was a transverse rupture. It was bright red, the colour deepest at the apex. The other was not nearly so prominent, of a yellow colour, the opening at the apex nearly circular. In both, the edges of the openings were everted. The walls of the uterus were very thick, and the uterine glands were very distinct. The cavity contained a considerable quantity of mucus. Two ova were found in it. They were five millimetres in diameter, white, the envelope tough and smooth. The contents could be seen to be fluid, with a dense white mass occupying about a fourth part at one side. One was situated in the upper part of the uterus, and was slightly adherent at two points to the lining membrane, which it dragged with it when moved. When separated some minute filiform shreds remained projecting from its surface. The uterus at this part was very vascular, tinged red, but there was no vascular connection, and the adhesion seemed to be caused by some accidental inflammatory action. The other ovum was situated in a pouch or hollow at the lower part of the uterus. It was not in any way attached, and rolled freely out of its bed, which was not more vascular than the neighbouring parts.

The second specimen containing ova was shot on the Campaspe on 4th November. It was seventeen inches long, in fine condition, with perfect fur, somewhat silvery on the abdomen. The right uterus was large, with thickened walls, smooth internally, and containing a good deal of mucus, but no ova. The corresponding ovary was little developed, and there were no recently ruptured ovisacs or appearance of any near maturity. The left uterus was very large, the walls thick, the inner surface smooth, very vascular, and covered with much mucus. Two ova, measuring four and a half and five millimetres, were found in it. They were whitish, softer than in the other specimen, the surface of the smaller slightly wrinkled. They were quite loose, and rolled freely. In the ovary were two recently ruptured ovisacs close together, bright red, with circular, everted openings. The mammary glands measured two inches by one when undisturbed and the cellular membrane not removed. The lobes were whitish, thick, and when cut into were found not to contain any milk.

Of the two in which the young or ova had been born, one was shot on the Campaspe on 27th October. It was seventeen inches long, with dark fur. There were no ova in either uterus, the walls of which were much thinner than in the last two. The right ovary was very little developed. The left was of much larger size, composed of numerous granules, the largest the size of No. 3 or 4 shot. I could not clearly detect the remains of any ruptured ovisacs. The mammary glands were largely developed, with numerous converging, thick, whitish lobes. They contained a considerable quantity of milk, which, examined microscopically, differed from cow's milk only in the smaller size of the globules.

The other in which the young had been born was dug, on 30th October, out of a burrow on the Axe Creek. It was caught alive. In the nest was also found a single young one, which the captor, thinking it of no value, threw into the creek. It was described to me as being scarcely an inch and a half in length, of a reddish colour, and perfectly smooth, without hair. The old one died before I got it. It was eighteen inches long, thin, and the fur ragged and dirty. The uterus and urogenital canal were empty. The mammary glands were very large, as in the last. I examined the opened burrow two days afterwards. The entrance was at the root of a tree, on the margin of a permanent water-hole. It extended up the bank, which at its extremity was about eight or ten feet high, following the contour of the ground, at a uniform depth of from eighteen inches to two feet, the total length being twenty feet. The nest, which must have been of large size, was composed of small gum-leaves and grass.

The unimpregnated female was sent from Hazelwood, in Gippsland, by Mr. E. Keighly. It was sixteen inches long, slender, the fur on the abdomen of a beautiful silvery grey, with a reddish-brown streak in the centre. The ovaries were small, granular, and contained no ripe ova. The mammary glands were very small, of a reddish colour, the lobes fleshy.

It has been recently announced that Mr. Caldwell, who has been investigating the reproduction of the Monotremata and Ceratodus in Queensland, has ascertained that the Ornithorhynchus is oviparous, and that the ova are meroblastic. The full report of his researches is anxiously looked for, and will be received with the greatest interest by all biologists. In the meantime, all that is certainly known is that ova of the size of those now shown have been found in the uterus, that young of one and a half to two inches in length and upwards have been found in the nest, and that these are suckled by the mother. The intermediate stages of their development are absolutely unknown. It is to be hoped that Mr. Caldwell has been able to clear up the early life history of these extraordinary creatures, the mystery shrouding which, we must all confess, is not very creditable to Australian naturalists and observers.

Art. XVI.—*Notes on the Meteorology of the Australian Alps.*

By James Stirling, F.L.S., Hon. Cor. Mem. Ro. Soc., S.A.

[Read 11th December, 1884.]

In an interesting report on the physical character and resources of Gippsland, by Mr. Skene, Surveyor-General, and Mr. R. B. Smyth, late Secretary for Mines, the following remarks concerning the meteorology of Gippsland are made :—

"It is much to be regretted that so little is known of the meteorology of Gippsland. A few observations have been made at one or more points on the coast, but no information is obtainable respecting the climate of that part of Gippsland bordering on the Dividing Range. In that area there are rich soils, much of the land is well grassed, and the enclosures which we saw under cultivation presented the most favourable aspects, and it is not creditable to the colony that vague and probably incorrect statements respecting the fall of rain, the temperature, and the occurrence of snowstorms cannot be met by an appeal to accurate records of the weather. It is our duty to recommend that no time be lost in instituting a series of meteorological observations in Gippsland; able and willing observers can be found in all towns and settlements, and with a little zeal at the seat of Government the work would proceed rapidly, and many of the representations which might deter settlers from occupying the higher lands would, we are convinced, be proved to be untrustworthy or exaggerated."

Acting on the suggestions embodied in the foregoing, and with a view to obtain some reliable data to aid physiographic researches in the Australian Alps, I commenced, during 1879, recording weather observations at Omeo, and, by a correspondence with some of the oldest settlers and other inhabitants, to elicit information respecting the weather during previous years. So far the results seem to confirm the suggestions made in the above-mentioned report; for an appeal to the records of the past five years would certainly indicate that the empirical representations as to the extreme severity of the climate are not altogether to be relied on, unless we assume, as some of the old residents still assert, the climate has undergone considerable modification during the period herein discussed. I have elsewhere* drawn attention to the excellent yields of cereals on the Omeo Plains during the past seven years, as disproving the notions of the early pastoral settlers, that it would only be an exceptional season in which wheat could be grown at these sub-Alpine elevations, viz., between 2500 and 3000 feet, owing, it was said, to late frosts, snow, and other unsuitable climatic conditions. The adaptability of various portions of the Australian Alps for most, if not all, the extra-tropical European, Asiatic, and North American vegetable products, is now being proved by the influx of settlers under the provisions of the Land Act 1869. Many localities between 3000 and 4000 feet—such as the Benambra Creek uplands, referred to in previous paper to the Royal Society,† have been selected and in occupation of resident farmers for some time. As an instance of what may be cultivated during summer even at higher levels, it may be interesting to note that cabbage, green peas, and other like culinary esculents are grown every season—January and February—at Dargo High Plains (4800 to 5000 feet above sea-level). The rapid growth of vegetation during mid-summer is a noticeable feature characteristic of these highlands, especially in those localities where rich volcanic soils are disintegrated from the tertiary basalts. As a summer sanatorium these highlands should become valuable. Even to one accustomed to mountain climbing, to cool pure air, and lovely scenery, the extreme grandeur and sublimity of the landscape, the freshness, rarity, and etherial purity of the air on our highest peaks and table-lands, has a most exhilarating and invigorating influence. The importance of meteorological observations from the highest elevations over South-east Australia can, I think, hardly be over-estimated, from the fact that there is probably no other country where the necessary conditions for studying weather phenomena are more favourable. Surrounded by oceanic expanses, and with just sufficient vertical relief to cause obstruction to wind and water circulation, the higher regions of Australia offer a splendid area for investigating many interesting meteorological changes.

* Notes on a Geological Sketch, Section Australian Alps. Trans. Royal Soc., S.A., 1884.

† Physical Features of Australian Alps. Trans. Royal Soc, Vict., p. 188.

The movements of circo-filum* in advance of cyclonic disturbances, could be observed with greater clearness from the Alpine stations free from the influence of smoke and other obstructions incidental to large cities in the lowlands. The causes which predominate in the deflection of extensive aërial currents, and the consequent condensation and precipitation of rain, snow, &c., over the Alps—whether such be due to ascensional movements of moisture-laden air;† to other thermal influence; or to the complex actions arising from the irregular barometric depressions and anti-cyclones which are constantly moving over the earth's surface in the temperate zones;‡ the protrusions of areas of high and low pressures, &c.,§ or other causes of like nature—would doubtless be more satisfactorily determined by establishing a chain of high-level observatories from the Western Australian ranges, across South Australia and the summits of the Australian Alps, to the Blue Mountains in New South Wales, and which might be expected to furnish data of sufficient scientific importance to enable our able Australian astronomers to establish some valuable weather laws, or, in addition to determining more fully the laws of meteorology prevailing over our Australian continent, enable them to reduce the already formulated theories of Europe and America to general laws, and, to quote the immortal Von Humboldt, "by a combination of thought and observation discern the constancy of phenomena in the midst of apparent change." The following statistics, relative to weather observations at Omeo, with notes on the higher regions surrounding this centre, are now given:—

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* Rev. Clement Lay, Q. J. of Met. Soc., Vol. IX., 1883.

† Rainfall of Cherrapunji, Q. J. of M. S., Vol. VII., 1882.

‡ Scott's Meteorology, p. 332.

§ President's Address, Vol. XVIII., p. 21, 1881, Trans. Ro. Soc. Vict.

RAINFALL.

TABLE *showing rainfall at Omeo for each month, the number of days upon which rain fell from June,* 1879, *to November,* 1884, *and the average per month for that period; by which it will be seen that October is the month of greatest mean rainfall and that January is the least, although the heaviest fall of rain during any single month occurred in February,* 1880, *and September,* 1883.

Year.	No. of Days.	January.	No. of Days.	February.	No. of Days.	March.	No. of Days.	April.	No. of Days.	May.	No. of Days.	June.	No. of Days.	July.	No. of Days.	August.	No. of Days.	September.	No. of Days.	October.	No. of Days.	November.	No. of Days.	December.	No. of Days during Year.	Totalforyear.
1879	..	..	..	..	..	..	..	..	..	..	..	1·39	10	1·76	8	1·70	15	2·60	10	4·26	9	2·59	8	1·31	..	..
1880	1	1·08	6	5·44	13	1·82	13	4·64	10	2·62	13	1·81	9	2·65	5	1·06	11	2·46	12	2·46	5	2·84	6	1·28	114	29·92
1881	5	0·86	4	2·24	7	3·42	3	1·17	5	1·09	9	1·49	7	0·41	9	1·84	11	1·53	10	2·81	12	3·52	8	1·60	90	21·98
1882	3	0·55	2	0·11	6	2·29	9	1·18	4	1·74	9	1·18	11	3·78	11	1·84	7	1·07	10	4·78	8	2·93	9	2·57	84	24·02
1883	5	0·91	6	1·73	5	0·85	5	1·18	11	1·41	5	1·43	10	1·48	7	1·73	13	5·02	14	2·47	8	1·44	9	1·17	98	20·82
1884	9	1·46	6	1·04	6	3·00	9	1·41	6	1·48	11	1·49	3	0·71	11	1·86	7	2·10	9	4·08	..	..	..	..	..	..
Mean	4·6	0·97	4·9	2·11	7·4	2·28	7·8	1·92	7·2	1·67	9·6	1·46	8·4	1·79	8·6	1·67	10·6	2·46	10·2	3·47	8·4	2·66	8	1·58	96	24·18

As the spring is fully three weeks later at Omeo, Omeo Plains, and the higher uplands at 3000-feet elevations, than on the lowlands up to 1000 feet, the October rains are generally most favourable to agricultural pursuits, and ensure seasonal regularity well adapted for cereal growths. The greatest fall of rain during 24 hours occurred on 28th February, 1880, when the gauge measured 3·38 inches, the wind blowing from S.W. That the amount of rainfall is greatest at the normal line of cloud flotation, approximately 3000 to 4000 feet in the Australian Alps, will be seen by comparing the records from those stations such as Grant, 4000 feet, in the Mitchell River, with those at Dargo, 1000 feet, in the same basin, only 14 miles distant. Thus during three or four years the average annual rainfall at Grant is probably 50 inches, at Dargo not more than 30 inches. Independently of the elevation, the situation of the station largely affects the precipitation of rain, which helps to increase the difference; for instance, the trend of the Dargo River valley from Dargo is southerly, and although partly exposed to the moisture-laden winds from the Pacific, it is nearly surrounded by high ranges. Grant, on the contrary, is on the crest of a high range fully exposed to the influence of south-westerly moisture-laden winds which sweep up the Dargo and Wongungarra Rivers, and to the north-western winds which are carried across the Dargo High Plains from the valley of the Ovens and tributaries. A station such as that which it is hoped may be established at Mount St. Bernard* would also show a proportionately large amount of snow or rainfall, as the ascensional movements of air from the valleys of the Ovens to the N.N.W., and the Wongungarra to the S.S.W., would doubtless be found to ensure a greater precipitation than other stations not so situated, although at a similar elevation of 5000 feet. The relation between winds and rainfall at Omeo is shown in the following table:—

Year.	North.	N.W.	N.E.	South.	S.W.	S.E.	E.	W.
1880	·20	7·26	1·65	—	22·49	·25	—	—
1881	·99	5·74	5 48	2 01	5·38	1·87	—	·20
1882	1·03	66·9	4·94	2·54	6.26	3·30	·12	·03
1883	·64	10·36	·87	3·43	4·90	1·09	·26	·18
Average ...	·71	7·51	3·24	2·00	9·76	1·63	·09	·10

* Since this was written I have erected instruments at Mount St. Bernard, 5036-feet elevation, in charge of Mr. Boustead.

Thus the average brought by southerly winds has exceeded that brought by northerly in the proportion 13·4 to 11·4. Arranged according to the seasons, we find the rainfall during spring is nearly double that of summer or winter. The heaviest flood on record occurred towards the close of the autumnal season during May, 1870.

Year.	Autumn.	Winter.	Spring.	Summer.	Year.
1880	9·08	5·52	7·52	7·83	1879-80
1881	5·68	3·74	7·84	4·38	1880-81
1882	5·21	6·80	8·78	2·26	1881-82
1883	3·44	4·64	8·93	4·21	1882-83
Average	5·85	5·19	8·27	4·67	

The probable annual rainfall at Omeo amounts to 25 inches, and the prevailing moisture-laden winds are south-westerly and north-westerly. During exceptional seasons heavy rains come from S. or S.E. Rev. Mr. Veal, of Bright, informs me that the rainy months at Bright, which is N.W. from Omeo in the valley of the Ovens, are June to October, and that the moisture-laden winds are prevailingly north-westerly; that the greatest fall of rain which has been recorded within 24 hours is 4·68 inches. As Bright is situated where the ascensional movements of north-westerly currents of air commence to sweep over the high Bogong Ranges to the east, it is not to be wondered at that the rainfall at this place should be the heaviest for the number of days upon which rain fell throughout the year among the official returns for different parts of the colony, averaging ·40 inches per day.

Snow.

Snow falls at all heights above 2000 feet, but at the lower levels seldom remains longer than a few days, thawing quickly as it falls, unless on the shaded hill-sides, where the frosts harden the crust. The distribution of snow seems to be affected by many complex causes; it is noticed that at similar elevations, in the same locality, the depth of snow after a fall is very unequal. It is possible that different radiating properties of various soils or rock masses* may exert some influence in the more rapid congelation or thawing of snow-flakes, or that parallel air currents may be of different

* Phil. Trans. London, 1847, p. 119.

degrees of moisture or of temperature. It is not unusual after a snowstorm to find at night that the snow which has fallen in the open is more luminous than that which has fallen in the shade of timber trees. This peculiar phosphorescence is no doubt due to exposure during the day of the many reflecting surfaces of the small speculæ of ice to the sun's rays, and to their retaining the light after the sun has set.* The year 1882 was apparently an exceptionally snowy season, both at Omeo and at the higher levels. Mr. Easton, an old resident, informs me that the greatest depth of snow which fell during 24 hours, within his recollection, was a little over a foot in the open at Omeo during July, 1869. On July, 1876, fully 11 inches fell at Omeo during 24 hours; since then the average fall at one time has not exceeded 6 inches. It must be borne in mind, however, that a uniform fall of one foot of snow at a time is very unusual in the British Islands,† and consequently even at 2000 feet elevation at this latitude, 37° south, such a fall would also be unusual. From a calculation of the quantity or depth of snow which fell at Omeo for the period under consideration, we shall find that the mean annual fall does not exceed 2 feet 3 inches, or nearly the same as that at New Jersey in North America. The heaviest fall on record at Grant (according to Mr. Harrison, jun.), which is nearly 2000 feet higher than Omeo, was from 2½ to 3 feet; while Mr. Boustead informs me that the average maximum fall of snow at Mount St. Bernard (5000 feet) measures 14 feet, with 20 to 30 feet in the drifts. I have observed near the summit of Mount Kosciusko, at an elevation of 7200 feet, masses of consolidated snow fully 30 feet deep—maiden glaciers—resting in the hollows of verdant slopes during mid-summer. And as the huge masses of tabular granite which form the rocky crests of this important mountain chain (presenting in many places escarpments fully 40 feet above the gentle slopes which surround them) are covered with snow early in June of each year, it is not improbable that the annual fall at this elevation amounts to 50 feet, corresponding to an annual rainfall of from 50 to 60 inches. I am not aware that there is any rule for increase of fall of snow with elevation. I am inclined to believe that there are vapour

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* Loomis' Met., p. 126.

† Scott's Met., p. 141.

planes, and that upon the percentage of moisture present in any of these zones, or the degrees of temperature—which are no doubt governed by many complex causes at present little understood—the fall of snow depends. From the following table of dates upon which snow fell at Omeo it will be seen that June, July, and August are snowy months.

1879.

	Min. Temp.	Wind.
June 18	32	S.W.
,, 28	35	,,
July 9	32	,,
,, 10	30	,,
,, 25	33	,,
Aug. 18	33	,,
Total depth of snow ..	1 ft. 6 in.	

1880.

	Min. Temp.	Wind.
June 8	31	S.W.
,, 15	40	N.E.
,, 17	33	N.W.
,, 19	27	N.E.
July 1	33	N.W.
,, 2	27	S.W.
,, 19	34	,,
,, 20	34	,,
Aug. 11	34	,,
Total depth of snow ..	2 ft. 3 in.	

1881.

	Min. Temp.	Wind.
June 4	37	N.W.
,, 7	31	,,
,, 8	31	,,
,, 19	31	,,
July 15	34	N.
,, 28	33	S.W.
Aug. 23	35	S.
Oct. 4	37	,,
,, 22	35	S.W.
Total depth of snow ..	2 ft. 3 in.	

1882.

	Min. Temp.	Wind.
June 1	35	N.
,, 21	29	N.E.
,, 24	38	,,
July 13	36	N.W.
,, 25	36	,,
,, 26	32	,,
,, 28	27	N.
,, 29	29	N.W.
,, 31	33	N.E.
Aug. 13	35	S.
Sept. 1	35	S.W.
,, 7	32	,,
Total depth of snow ..	3 ft.	

1883.

	Min. Temp.	Wind.
July 10	30	S.W.
,, 27	32	N.
,, 28	33	,,
Aug. 4	32	S.
Sept. 13	32	S.W.
,, 14	32	S.
Total depth of snow ..	3 ft.	

1884.

	Min. Temp.	Wind.
Aug. 18	30	S.W.
,, 19	30	,,
Total depth of snow ..	1 ft.	

Hail.

Hailstones, although frequent in the higher regions of the Australian Alps during summer and autumn, are not so at sub-alpine altitudes, although it is somewhat remarkable that the size of the hailstones is frequently much larger at elevations of 2000 to 4000 feet than at higher levels. I have noted hailstones fully half an inch to three-quarters of an inch in diameter,* and during October last some curiously-

* Fell at Gelantipy during May, 1869.

shaped masses fell at Dargo, fully half an inch in diameter; some were ovoid, and others not unlike a truncated cone. As a rule, the hailstones come from the westward, and are generally accompanied by electric discharges or strong wind.

Moisture of the Atmosphere.

Unfortunately the hygrometric records do not extend further back than May, 1883, when wet and dry bulb thermometers were supplied me by Mr. Ellery. The following table exhibits the mean temperature of dew-point for each month from May, 1883, to November, 1884, and for the seasons of the year. The results for winter are more complete, being the mean of two years. It will be seen that the lowest mean temperature of the dew-point is reached during the month of July, and highest during February, corresponding in this respect to the temperature of the air :—

December ...	50·58	March	50·39	June	38·04	September	40·51
January ...	52·18	April	48·66	July	36·03	October	45·79
February ...	53·08	May ...	38·33	August	37·93	November	49·95
Mean Summer	51·94	Autumn	45·79	Winter	36·66	Spring ...	45·35

—giving a mean annual temperature of the dew-point of 45·16. During winter months, when the temperature of the air fell below freezing point, I have discarded the results owing to the difficulty of registering the dew-point with the dry and wet bulb thermometers.

I have not given the relative humidity or elastic force of vapour, as it was thought better to defer these until a longer series of observations have been made. It may be interesting to note that the humidity of the air varies greatly during the summer months, especially at the higher elevations; and at the lower levels, as at Omeo, the shifting of the wind from N. to S.W. and S. sometimes causes an excessive humidity, as shown by the dense fogs which frequently envelope the higher points over 4000 feet; during summer a feature connected with such hygrometric conditions are what is locally termed southern fogs.

Fogs.

Often when the sky is clear during the morning towards afternoon dense masses of vapour are seen floating up the valleys of the Tambo and other streams from the seaboard, at a mean elevation of 3000 feet, and settling on the ranges round Omeo, causing a rapid fall of the temperature. These fogs are, according to the old residents, generally the forerunners of dry seasons, and are altogether distinct from the ordinary radiation fogs of Sir M. Herschel.* Last Christmas, while botanising on Mount Kosciusko, an opportunity was afforded the writer of watching the progress of one of these southern fogs coming from the seaboard. A warm cloudless morning, with the thermometer 92 in the sun, at an elevation of 7000 feet at one p.m., was followed by a warm cloudless afternoon; until five p.m. large masses of what appeared to be dense nimbus clouds were seen on the southern horizon; these gradually enlarged, and could be seen surging up the valleys. At last the temperature sank to 43° Fahr., when a dense fog suddenly enveloped the summit of the mountain, and in a few minutes began to clear off again, sinking to a level of about 6000 feet, and there remained like a wide expanse of silvery ocean during the clear moonlight night, until dissipated by the warm golden rays of the rising sun. A peculiar feature of such fogs is that the upper part is cooler than the lower—*i.e.*, when the fog-masses are rising radiation of heat is greater at the upper than at the lower part.

Clouds.

The following table shows the mean or average number of days upon which the sky was overcast, cloudy, and clear at nine a.m. for each month of the year. These results are obtained from the daily observations between 1st April, 1879, and 1st November, 1884:—

Months.	O'cast.	Cloudy.	Clear.	Months.	O'cast.	Cloudy.	Clear.
January	3	14·6	13·4	August	5·3	14·2	11·5
February ..	2·8	13	12·2	September ..	9	11·7	10·1
March	4·8	16·6	9·6	October.. ..	4	16·8	10·2
April	5	17·5	7·5	November ..	3·5	16·3	10·2
May	5	17·3	8·9	December ..	3	16·8	9·2
June	3·4	16·3	10·3				
July	7	13·7	10·3	Yearly Average	55·8	184·8	123·4

* Scott's Meteorology, p. 121.

SEASONS.

	SPRING.			SUMMER.			AUTUMN.			WINTER.		
	O'cast	Cldy.	Clear.	O'cast	Cldy.	Clear.	O'cast	Cldy.	Clear.	O'cast	Cldy.	Clear.
Mean..	14·8	51·4	26·0	8·8	44·4	44·8	16·5	44·8	30·5	15·7	44·2	32·1

It will be observed, that although the number of cloudy days is in excess of the clear for the entire year, yet the latter more than double those upon which the sky was overcast. It is also noticeable that the number of clear days is greater during summer and winter than in the spring or autumn. The beautifully clear cool days of winter are a noticeable feature in the climate of the Australian Alps, although frequently preceded by hard frosts and occasionally followed by heavy snow falls.

Frosts.

As the time of year in which frosts occur has an important influence on the success or otherwise of agricultural operations, it becomes interesting to note how often they have been found to take place within the period herein discussed. The following table gives the number of days during each month since 1879 upon which they have occurred:—

1879.		1880.		1881.		1882.		1883.		1884.	
	Days.		Days.		Days.		Days.		Days.		Days.
June ..	5	June ..	5	May ..	4	May ..	2	May ..	2	May ..	4
July ..	4	July ..	8	June ..	5	June ..	2	June ..	6	June ..	6
Aug. ..	6	Aug. ..	1	July ..	3	July ..	10	July ..	6	July ..	12
		Sept. ..	2	Aug. ..	2	Aug. ..	3	Aug. ..	4	Aug. ..	3
						Sept. ..	1	Sept. ..	1	Sept. ..	1
Total No. of days for year	15		16		14		18		19		26

Mean No. of days per month—May, 2; June, 4·8; July, 7·2; August, 3·2; September, ·83.

It will be seen by the above that the present year has been unusually frosty, and ranged from May to 18th September. As the seasons are later at sub-alpine habitats above 2000 feet, the September frosts, which might prove injurious in the lowlands, are not so much so at these elevations. The month of July is noted for severe and successive hard frosts, the minimum temperature during such frosts ranging from 32° to 19° Fahr. It is possible that the occurrence during September of occasionally severe frosts has led to the statements of the early pastoral settlers as to the uncertainty of cereal growths. These facts serve to support the opinion of the Surveyor-General and late Secretary for Mines, as quoted at the commencement of this paper. It is only in the valleys that the severest frosts take place. I have observed lowland exotic plants flourishing on the ridges which perished under extreme frost in the valleys, the temperature being more equable at the former habitat than in the latter.

Temperature.

The range of temperature at sub-alpine elevations is apparently large, while the rapidity of the changes increases with the elevation (see remarks on Climate at 5000 feet, p. 141). The mean annual temperature deduced from the following table gives 53° 34′, almost the same as at Ballarat,* although there is probably a greater absolute range of annual temperature at Omeo than at the former place. The highest recorded temperature in the shade at Omeo for the period herein discussed occurred on the 21st January, 1880, when the maximum thermometer registered 105° at 1.30 p.m.; and the lowest in July, 1883, at 6.10 a.m.—the occasion of a severe frost, when the minimum thermometer registered 19° Fahr., or 13° below freezing point—or an absolute range of 128°, nearly as large as Chicago, Illinois, America.†

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* Exhib. Essays, p. 5.

† Loomis' Met., p. 272.

TABLE *showing maximum, minimum, range, and mean monthly temperature in the shade, from April,* 1879, *to November,* 1884, *at Omeo.*

	Months.	1879.				1880.				1881.				1882.				1883.				1884.			
		Max.	Min.	Rge.	Mean	Max.	Min.	Rge.	Mean	Max.	Min.	Rge.	Mean	Max.	Min.	Rge.	Mean	Max.	Min.	Rge.	Mean	Max.	Min.	R ge.	Mean
Summer	December ..	...	...	...	...	76·1	44·0	32·1	60·04	81·0	49·0	32·0	65·0	...	47·5	...	...	77·0	47·1	29·9	62·6	...	...	...	...
	January ...	...	...	...	...	88·5	47·1	41·4	67·8	87·5	47·7	39·8	67·6	85·0	50·0	35·0	67·6	...	49·7	...	...	78·5	44·4	34·1	61·4
	February ...	...	...	...	...	83·3	50·5	32·8	66·9	87·8	48·0	39·8	67·9	83·8	49·4	34·4	66·6	...	52·7	...	...	78·5	49·4	29·1	63·9
	Mean temp. for season	...	...	...	...	82·6	47·2	35·4	65·0	85·4	46·5	37·2	66·8	84·4?	48·9	...	67·1?	...	49·8	..	62·6?	...	...	...	62·6?
Autumn	March ...	...	...	...	...	70·2	50·4	19·8	60·3	80·1	47·6	32·5	63·9	77·8	44·3	33·5	61·0	...	53·7	...	...	77·5	38·6	38·9	57·6
	April ...	73·7	39·3	34·4	56·5	66·9	44·9	22·0	55·9	73·1	39·2	33·9	56·2	...	37·9	...	...	...	51·8	...	...	68·0	47·4	20·6	57·7
	May ...	56·2	38·1	48·1	47·2	53·2	37·2	16·1	45·2	67·3	39·1	28·2	53·2	...	37·9	...	...	57·8	35·8	22·0	46·8	55·2	35·4	19·8	42·2
	Mean temp. for season	...	...	...	51·8?	63·1	44·1	19·3	53·8	73·5	41·9	31·5	57·7	...	40·0	...	...	...	47·1	...	...	66·9	40·9	26·4	52·5
Winter	June ...	49·7	32·4	17·3	40·7	51·0	33·0	18·0	42·0	56·2	32·9	23·3	49·5	...	32·4	...	...	53·2	35·4	17·8	44·3	53·3	33·5	19·8	43·4
	July ...	51·7	26·9	24·8	39·3	50·1	30·1	20·0	40·1	55·7	31·2	24·5	43·4	...	32·6	...	...	50·0	31·7	18·3	40·9	52·4	26·0	26·4	39·2
	August ...	53·7	34·8	18·9	44·2	56·5	32·2	24·3	49·9	58·2	35·2	23·0	46·6	..	34·3	...	...	56·2	33·4	22·8	49·8	60·1	32·2	27·9	46·5
	Mean temp. for season	51·7	31·3	20·3	41·4	52·5	31·7	20·7	44·0	56·7	33·1	23·6	46·5	...	33·1	...	...	53·1	33·5	19·6	45·0	55·2	30·5	24·3	43·0
Spring	September ...	61·2	38·9	22·3	50·1	65·0	35·8	29·2	50·4	63·8	36·8	27·0	50·3	...	37·9	...	...	55·7	36·2	19·5	45·9	64·5	35·4	29·1	49·9
	October ...	65·7	42·2	23·5	53·9	72·3	36·8	35·5	54·5	66·2	41·0	25·2	53·6	...	41·0	...	...	60·8	41·0	19·8	50·3	...	...	...	...
	November ...	70·3	41·8	28·5	56·1	79·9	42·5	37·4	61·1	74·5	43·8	30·7	59·2	...	45·1	...	...	65·7	43·5	22·2	54·6	...	...	...	...
	Mean temp. for season	65·7	40·9	24·7	53·3	72·4	38·3	34·1	55·3	68·1	40·5	27·6	54·3	...	41·3	...	...	60·7	40·2	20·5	50·2	...	...	...	...

From this table the following mean monthly temperatures are obtained :—

January	66·10	August	47·07
February	66·07	September	49·26
March	60·70	October	53·07
April	56·28	November	57·75
May...	46·92	December	62·03
June	43·92		
July...	40·58	Mean annual temp.	53·34

And also the mean temperature for the seasons, as follow :—

Spring, 53 ; Summer, 64 ; Autumn, 54 ; Winter, 43.

The variation to which the law of decrease of temperature with elevation is subject is well shown by many localities in the Australian Alps, particularly by the presence of many tropic types of vegetation in the humid soils on the most southern slopes, at elevations of 3000 feet ; and the mean temperature is probably greater—at similar elevations—on the northern sunny slopes than on the moist southern slopes ; and the absolute range of temperature is also greater on the former than on the latter at similar elevations. Again, those localities open to the cooling influence of polar winds would, doubtless, show a lower mean annual temperature than those localities on the same latitude, at the same elevation, although exposed to the warming influence of equatorial winds.

The following table gives the mean monthly temperature of the surface of the ground at 9 a.m., and also that for the seasons :—

Summer.		Autumn.		Winter.		Spring.	
December..	79·52	March ..	70·93	June ..	46·43	September	57·27
January ..	79·60	April ..	66·00	July ..	45·41	October ..	65·04
February ..	81·82	May ..	49·56	August ..	55·37	November..	70·00
Mean temp.	80·45	Mean temp.	62·16	Mean temp.	49·07	Mean temp.	64·10

This gives a mean annual surface temperature in the sun of 63° 88′, or a little over 10 degrees higher than the mean annual temperature of the air in the shade, four feet from the ground. This large mean annual surface temperature must necessarily affect the amount of spontaneous evaporation at Omeo.

The atmometric records are only available from October, 1883, to November of the present year; and the resulting figures are therefore an approximation only, yet sufficient, I think, to indicate that spontaneous evaporation is in excess of rainfall at Omeo. A noticeable instance of evaporation over a large surface is furnished by Lake Omeo, which in 1882 was a sheet of water 2 miles long by 1 mile broad, and with an average depth of probably 2 feet 6 inches, or less. This lake became dry during the present year, and this accords with the following approximate results from the evapometer at Omeo, *e.g.*, 30½ inches per annum. It must be borne in mind, however, that the evaporation from a sheet of water freely exposed to the accelerating influence of summer winds, would be greater than that from a situation sheltered by high ranges. It is a remarkable fact that during seasons of severe frosts many small creeks and water channels become dried up thereby.

December ..	3·56	March ..	2·80	June ..	·50	September ..	2·50
January ..	5·50	April ..	1·10	July ..	·30	October ..	4·28
February ..	4·68	May ..	·80	August ..	·75	November ..	3·75
Total for season	13·74		4·70		1·55		10·53

Winds.

The following table exhibits the average number of days the wind blew from the different points of the compass, and the mean velocity in miles per hour for each month of the year, and the mean velocity for each point for different seasons :—

MONTHS.		N.		N.E.		N.W.		S.		S.E.		S.W.		E.		W.		Mean velocity of wind per month per hour.
		Mean No. of days.	Mean velocity per hour	Mean No. of days.	Mean velocity per hour	Mean No. of days.	Mean velocity per hour	Mean Mo. of days.	Mean velocity per hour	Mean No. of days.	Mean velocity per hour	Mean No. of days.	Mean velocity per hour	Mean No. of days.	Mean velocity per hour	Mean No. of days.	Mean velocity per hour	
Summer	December	2·7	11	5·4	14	2·2	15	3	8	2	9	4	11	3	10	..	..	11·1
	January	3·7	15	5·5	8	2·7	17	3·7	9	2·6	11	4·8	10	2	8	1·5	10	11
	February	2	8	5	9	2	8	4	12	2	8	2·7	11	2	·9	..	..	9·3
		8·4	11·4	15·9	10·3	6·9	13·3	10·7	9·6	6·6	9·3	11·5	11	7	9	1·5	10	10·5
Autumn	March	2·3	9	4·6	8	1·5	8	1	8	1	9	2·7	10	1·5	11	..	..	9
	April	2·5	10	6 0	12	2·6	13	1·5	10	2	15	4·6	8	1	8	..	..	10·9
	May	2·3	8	3·7	9	6 7	10	1·5	8	3	8	4·3	10	2	13	..	..	9·4
		7·1	9	14·3	9·6	10·8	10·3	4	9	6	10·6	11·6	9·3	4·5	10·6	..	..	9·7
Winter	June	4	9	7	10	4·6	14	1·3	9	..	..	2·5	8	2	8	1	8	9·5
	July	3	10	5·5	10	5·2	8	1	8	1	8	3·6	9	2	8	1	8	8·7
	August	3·6	10	7·5	19	3	9	3	8	2	8	2·5	10	2	9	..	..	10·4
		10 6	9·6	20	12·9	12·8	10·3	5·3	8·3	3	8	8 6	9	6	8·3	2	8	9·5
Spring	September	5·5	9	7	9	3·6	12	2	12	2·6	10	2·5	9	1·5	9	1	8	9·7
	October	4·5	10	6·5	8	2	14	1 6	8	2·6	8	3	11	3·5	8	..	..	11·1
	November	1	8	7·7	8	4·3	11	3	10	3·7	8	5·2	10	..	..	..	..	9·1
		11	9	21·2	8·3	9·9	12·3	6·6	10	9	8·6	10·7	10	5	8·5	1	8	10·1
		..	9·3	..	10·2	..	11·5	..	9·2	..	9·1	..	9·8	..	9·1	..	8·6	9·95

The number of times which the wind blew from the N.E. being greatly in excess of that from any other cardinal point, may be partly accounted for by the trend of the Livingstone Creek Valley and the Dividing Range to the east deflecting the north and north-north-westerly currents of air. The relatively small velocities are also probably owing to the somewhat sheltered position of the observatory, partly surrounded by high ranges, which intercept the strong N.W. to S.W. winds. The greatest mean velocity of the wind occurs during spring and summer, and principally with north-westerly currents of air. The greatest velocity recorded at Omeo with a cup anemometer was forty-eight miles per hour during a strong gale from the N.N.W. Anemometrical records from Mount Hotham would show interesting results, as the strong westerly gales which flow at this elevation are a noticeable feature during the equinoctial season. On the whole, westerly winds may be said to predominate in the Australian Alps, although local influences at lower sub-alpine altitudes cause deflection and obstruction to aërial currents, as shown by the results at Omeo, where the prevailing winds are northerly. A remarkable phenomenon connected with the temperature of wind which has been frequently noticed in the sub-alpine valleys of the Australian Alps is the occasional whiffs, during frosty mornings, of warm currents of air, producing an irritation of the throat and nose similar to that felt when ozone is largely present in the atmosphere. How far these peculiar abnormal air-movements are due to electrical agencies, or to the actual presence of isolated masses of warm dry air, which have come to us from the heated interior of Australia, I am unable to suggest; I simply note the fact as one which requires some explanation. Owing to the situation of Omeo with reference to the higher regions of the Australian Alps, hot winds are comparatively unknown; the N.N.W. and N.W. hot winds, during summer, come down to us cooled by their passage over the Bogong High Plains.

Pressure of the Atmosphere.

The maximum of mean monthly pressure of the atmosphere occurs during August, while the greatest absolute pressure for the period during which observations were taken occurred on 30th July, 1883, when the reading of the barometer, reduced to sea level and temperature 32° Fahr., gave 30·280. The lowest reading of the barometer, reduced to sea level and 32° Fahr., took place on 28th December, 1881, viz., 29·600, with squalls from N. followed by a thunderstorm. As a rule the barometer at Omeo stands lower with the winds from N.N.E. to N.N.W., and higher from S.S.W. to S.E., although frequent departures from this rule occur.

Summer	Dec. ..	30·040	Autumn	March	30·120	Winter	June ..	30·136	Spring	Sept...	30·070
	Jan. ..	29·683		April	30·153		July ..	30·210		Oct. ..	30·090
	Feb. ..	30·053		May ..	30·113		Aug. ..	30·266		Nov. ..	29·920
Mean Summer	..	29·925	Mean Autumn		30·128	Mean Winter	..	30·214	Mean Spring		30·126

The mean pressure during winter is greatest, and during summer least.

The following table shows the mean range in pressure for the different months, and also that for the seasons:—

December ..	·656	March ..	·610	June	·860	September ..	·825
January ..	·616	April	·506	July	·826	October ..	·595
February ..	·685	May	·953	August ..	·826	November ..	·746
Mean Season	·645	Mean Season	·689	Mean Season	·837	Mean Spring	·722

This gives a mean monthly range for the year of ·717. The rule for decrease of pressure with altitude would seem to be subject to slight variations caused by lateral pressures, aërial currents sweeping up the narrow valleys, and by thermal influences of a local character, so that the difference of surface configurations and surroundings of two stations on the same parallels of latitude, and at the same altitude, may differ slightly in their barometric pressures.

The following records, kindly supplied by Mr. William Boustead of Mount St. Bernard, are very interesting, as showing the character of the climate in the higher regions of Victoria during winter. Unfortunately no records of maximum or minimum temperatures are available, although the ten a.m. observations of thermometer in the shade are extremely valuable. From this and other data, collected when travelling over different parts of the Alps, the following abstract of the climate at elevations of 5000 to 6000 feet is obtained. The mean winter temperature at Mount St.

Bernard, 5060 feet, would appear to be 33·91 Fahr., or about two degrees above freezing point. The lowest temperature recorded from ten a.m. observations is 29°, and the maximum 70° in the shade, 90° in the sun. July and August are the coldest months, February and March the warmest. The seasons of maximum cold for the past thirteen years appear to have been 1876, 1881, and 1882; and the season of greatest heat, 1882. The fall of snow sometimes commences as early as April—although May is the usual month—and begins to disappear during September, sometimes October. April is frequently a rainy month, and during January and February thunderstorms are prevalent, invariably from the westward. As a rule the prevailing winds are from—

S.W. to N.W.	during	summer.
S.W to S.E.	„	autumn.
N.W.	„	winter.
W. to N.W.	„	spring.

The wind blows with great force at these elevations, and the changes are very rapid. Mr. Boustead informs me that he has had thick fogs with rain all day at Mount St. Bernard, while three miles lower down, or at an elevation of 4000 feet, the sun has been shining in a clear sky! He also remarks that it is an unusual thing to have a Christmas without snow.

WEATHER *observations made at Mt. St. Bernard*, 5060 *ft. above sea-level, during winter months, June, July, & Aug.*, 1882.

Date.	Therm. in shade.	JUNE. Remarks.	Therm. in shade.	JULY. Remarks.	Therm. in shade.	AUGUST. Remarks.
1	...	...	31	Hard frost, and strong N.W. gales	30	Snow and thick fogs all day
2	...	...	31	,, ,,	30	N.W. winds, con. snow
3	...	...	32	,, ,, clear	32	Strong N.W. winds, con. snow
4	...	...	32	N.W. gales and fogs	30	Thick fogs, ,,
5	...	...	34	,, ,,	30	Snowing all day
6	...	...	36	Strong wind with rain	32	Snow in morng., fine aftern.
7	...	...	35	Strong N.W. wind with showers	32	Clear light winds, snow in aft.
8	...	...	38	Moderate N.W. winds, thick fogs	30	Lt. N.W. winds, slight snow
9	..	...	35	Light winds and snow	32	Clear, latter part cloudy
10	...	...	32	Str. N.W. gales, hard frost, snow	32	Hard frost, con. fair weather
11	...	...	30	Frost, fogs, snow, and heavy gales	32	,, light winds, snow
12	...	...	30	Frost, fogs, and snow	32	,, ,,
13	38	Moderate S.E. winds with snow	30	,, and continued snow	34	Fine and clear all day
14	34	Strong N. to N.W. winds with heavy snow	30	,, and light N.W. winds	36	Light N.W. winds, fine & clear
15	32	Continued snow	30	,, ,,	34	Hard frosts, ,,
16	32	N.W. winds and snow	30	Strong S.E. winds and frost	32	Strong N.W. gales, with snow
17	34	Continued snow	32	Moderate S.E. winds and fine	32	,, sleet and rain
18	34	N.W. winds and snow	32	Frosts, fine and clear	34	Mod. N.W. winds, thick fogs
19	34	Light N.W. winds and snow	35	,, ,, noon	36	Frosts, fine and clear
20	35	Light winds with snow	35	,, ,,	48	N.W. winds, fine and clear
21	38	Fine clear weather	35	N.W. winds, fine weather	42	Light winds, rain, cloudy
22	38	,, ,,	38	Frosts, light winds, clear	44	,, thick fogs
23	36	,, ,,	36	Frosts, strong winds, cloudy	46	Fine and clear all day
24	30	Strong N.W. gales, hard frost, thick fogs	34	N.W. gales, hail and snow	46	,, ,,
25	36	Moderate and clear	32	Strong N.W. winds, snow and fogs	46	Strong winds, thick fogs
26	36	Fresh S.E. winds and fine, fogs in evening	30	Heavy snows and fogs	46	,, ,, rain
27	34	Fine weather	32	Light N.W. winds, snow showers	46	Raining all day, sn. thawing
28	34	Strong winds and thick fogs	30	,, ,, frosts	46	Light rain, thick fogs
29	32	Hard frost, heavy gales and fogs	30	Frost, light N.W. winds, clear	44	Strong N.W. winds, thick fogs
30	30	Strong winds, moderate towards night	30	Strong N.W. winds, snow and frost	42	Rain and snow all day
31			30	Cloudy, and snowing all day	40	Strong N.W. gales, with snow
Means	34·27		32·48		37·03	

WEATHER *observations made at Mt. St. Bernard*, 5060 *ft. above sea-level, during winter months, June, July, & Aug.*, 1883.

Date.	Therm. in shade.	JUNE. Remarks.	Therm. in shade.	JULY. Remarks.	Therm. in shade.	AUGUST. Remarks.
1	32	Moderate N.W. winds with sleet	36	Strong N.W. gales, rain and fogs	40	Con. fine clear weather.
2	30	Thick fogs, rain, and sleet	36	,, thick fogs, rain	42	S.W. winds ,,
3	32	,, N.W. wind, light snow	36	Thick fogs, mod. and fine in evening	42	Light N.W. winds, light frosts
4	34	Moderate N.W. winds, fair weather	38	Moderate S.W. winds, clear weather	38	Light W. winds, rain, snow
5	36	,, S.E. ,, thick fogs	38	Moderate N.W. winds, ,,	36	Strong W. winds, snow, fogs
6	36	,, ,, ,, clear weather	38	,, heavy fogs	32	Cloudy cold weather all day
7	40	Light S. winds, thick fogs	34	,, fogs, snow, rain	32	Strong N.W. winds, cloudy
8	38	Moderate S.E. winds, clear weather	32	Strong N.W. gales, snow, fogs, frost	34	Light N.W. winds, dense fogs
9	40	Fine and clear all day	32	Strong W. gales, with snow	34	Strong W. ,, ,,
10	40	Light N.W. winds, and fine weather	30	Dense fogs, snowing heavily	34	,, N.W. gales, cloudy
11	44	,, ,,	30	Strong W. gales, sleet and snow	38	,, ,, heavy snow, cold
12	44	,, thick fogs, cloudy	30	Str. N.W. gales, dense fogs, rain, sleet	38	,, ,, snowing heavily
13	40	N.W. winds, overcast, cloudy	32	,, snow and sleet	36	,, ,, with snow
14	40	Strong N.W. winds, thick fogs, sleet	34	,, thick fogs	36	,, ,, ,, heavy fogs
15	38	,, dense fogs, heavy rain	32	,, ,, very cold	36	,, ,, ,, ,,
16	38	,, ,, ,,	32	Hard frosts, snow, dense fogs, ,,	36	,, ,, heavy fogs, frosts
17	38	Thick foggy weather	30	W. wind, hard frosts, clear	36	Heavy N.W. gales, thick fogs, rain
18	36	N.W. winds, heavy fogs	30	S.W. winds, cloudy, severe frosts	36	Heavy rains, W. gales
19	36	Moderate N.W. winds, heavy fogs	34	Light S. wind, snow, hard frosts	36	,, ,,
20	38	Heavy fogs, rain in evening	36	Fine and clear all day ,,	34	Strong N.W. gales, snow, fogs
21	36	Light N.W. winds, heavy fogs	36	,, ,,	38	Light S.W. winds, hard frosts
22	36	Strong N.W. gales, heavy rains	36	Cloudy weather, light snow	38	Strong ,, ,,
23	36	,, sleet, rain, fogs	38	Fine and clear all day, hard frosts	38	,, ,, fine weather
24	34	,, snow, frosts, fogs	36	,, N.W. wind ,,	38	,, ,, ,,
25	34	N.W. wind, sleet, and heavy fogs	36	Light N.W. winds, ,,	32	Light N.W. winds, cloudy
26	34	N.W. wind, dense fogs, sleet and rain	34	Strong W. ,, snow, frosts	32	Strong N.W. gales, very cold
27	34	Strong N.W. gales, fogs, hail and rain	30	,, ,, snowing, very cold	36	,, ,,
28	36	,, dense fogs, light rain	30	Moderate N.W. winds, snowing	36	,, clear weather
29	36	N.W. winds, dense fogs	32	S.W. winds, clear weather	36	Light N.W. winds ,,
30	34	Str. N.W. winds, dense fogs, light rain	34	W. wind, and fine snow	36	,, and snow
31			38	S.W. wind, and fine weather	36	,, ,,
Means	36·66		33·83		35·22	

In addition to the various meteorological elements herein referred to, the amount of direct sunshine and percentage of ozone in the atmosphere is now observed at Omeo, but as the period of observation does not extend beyond July of present year the results are not given. It may be remarked, however, that the ozone reaction seems to be greatest with winds from the south, and least with northerly winds, although further more extended observations may modify this result. In respect to the sunshine recorder, I may state that from a number experiments made with a view to obtain an inexpensive instrument, I have found that a blown glass sphere filled with water, and with a glass tube bent like a syphon, to allow for expansion of the water during great heat, acts admirably; the heat rays passing through the vessel, without much interference, burning a line on the prepared paper at the true focal length. The only difficulty in using this instrument is the rapid expansion due to the reduced temperature—*i.e.*, when the water freezes in the sphere in cold weather; but as the temperature during the day never sinks below the freezing-point—*i.e.*, when the sun is shining—this difficulty is obviated by removing the instrument, which is on a movable stand, inside at night. Various other forms of meteorological phenomena—such as optical, electrical, &c.—remain to be discussed; but as these have not, so far as I am aware, any direct influence in estimating the probable climatology of a district, I have not thought it necessary to furnish any particulars of records taken of the former in the present paper.

Traces of a Former Glacial Period in the Australian Alps.

In concluding the present introduction to the Meteorology of the Australian Alps, I have great pleasure in reporting what may, I think, be considered as conclusive evidence of the existence of a glacial period in the Australian Alps during Post-miocene Times. The able arguments set forth by Mr. Griffiths, in his "Evidences of a Glacial Period in Victoria during Post-miocene Times," read before this Society on 19th March last, led me to examine carefully the surroundings of the Dry Gully and Lake Omeo areas, with the results that I have been fortunate enough to discover undoubted evidences of glacial action. Distinct rock striæ on hard filsitic and porphyritic rocks at Omeo Plains; on the gneissose rocks, Livingstone Creek, near Omeo; groovings and markings on the bottom of the old lake bed at Dry Gully; numerous erratic and ice-worn boulders, both on the margin of Omeo Plains, and in the Dry Gully, and Livingstone Creek gold workings, which indicate translocating agencies distinct from ordinary fluvial action; as well as other interesting relics, all pointing to a period of great refrigeration culminating in an ice-covered region. I have to thank Mr. Griffiths for the incentive to examine with greater circumspection the geological features of the area with which I thought I had been previously familiar, with the result that I am able to confirm his splendid theoretical deductions by an appeal to actual facts capable of direct verification on the ground. I have been careful not to confound these rock striæ with the slickensides so frequent in faulted geological districts, which would be produced by the downward slidings and crushings of great rock masses during times of volcanic activities. The situation and character of these glaciated rock surfaces are distinctive, and can hardly be mistaken for slickensides. The whole of the proofs which I have to offer in support of Mr. Griffiths' hypothesis, from geological and botanical data, will, I trust, form the subject-matter for a subsequent paper. In the meantime it is hoped that the announcement of the discovery of geological evidences of glaciation in the Australian Alps may not be without interest, and direct attention to the question of pre-existing meteorological changes, suggesting thoughtful inquiry as to the great cosmic causes which have slowly but surely dominated in the evolution of existing climatic conditions from the cycling meteorological changes of past time.*

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* Since the above was written Dr. von Lendenfeld reports the discovery of evidences of glacial action on Mount Kosciusko, *vide* telegram in *Argus* newspaper of January 16th, 1885.

Art. XVII.—*On the Extinction of Waves at the Entrance of Harbours.*

By Edward Davy, L.S.A., M.R.C.S.

[Read 11th December, 1884.]

To prevent the access of a heavy sea into a shipping harbour has always been a desideratum. This object can be accomplished by means of what is called a breakwater—namely, a strong stone wall, built up from the bottom of the sea; and what has been called a floating breakwater, as a cheap substitute, is probably a fallacy.

If a principle can be pointed out by which, at an enormously smaller expense, the same object can be even partially obtained, there is no doubt a benefit would be conferred on the world. I therefore offer the following in the hope that others capable of reasoning correctly on the matter will take the subject up.

The contrivance which I propose, and which, provisionally, I will call a Wave Extinguisher, consists of three parts—

First, a float.
Second, a moorage.
Third, a tether.

I shall describe the contrivance as a unit, on the understanding that any number of them may be required for use.

First, the Float.—The float may be a log of light wood, or hollow barrel of air, made of whatever material will suit.

The Moorage may be a basket of durable wood at the bottom of the sea, sufficiently loaded with stones (with the aid of the tether) to prevent the float from rising with the waves.

The Tether will be a rope or chain of the length to be required, according to circumstances. Now, it will appear that on the approach of a wave the float, being so confined, will be unable to rise with or to the top of it, and will consequently be submerged in it; in so doing, it becomes, for the time being, a part and parcel of that wave—displacing water which thus takes its place in the trough between the waves. As the wave passes on it is, of course, lessened by a bulk equal to that of the float it has left behind it.

To carry this simple principle out for practical purposes, we have now to come to other considerations. Let us suppose the apparent height of a wave, as seen from a boat in the bottom of the trough, to be twenty feet; now, as half of this elevation belongs to the trough, the actual height of the wave above the mean level of the sea is only ten feet; supposing the sides to be inclined at an angle of forty-five degrees, the area of a transverse section of that wave will be one hundred square feet; and that area, multiplied by the length, will give the solid bulk of all the floats required to extinguish it.

A number of these elements in a double or multiplied row would probably be more convenient than a few large ones, and the construction, not being continuous, might be carried out progressively until sufficiently effective.

One advantage in contradistinction to a sea stone wall would be, that the depth of the water would make very little difference in the expense—being a question of length of tether only.

Among the obvious objections to the scheme must be mentioned the variations of tide—the length of tether suiting one tide not being suitable for another. In reference to this point, it would seem more important to provide against waves at high tides than at low ones; but in any case this is only a question of multiplying the elements, or altering the form of the floats, probably by lengthening in the perpendicular direction.

However, the scheme, such as it is, is at the service of the public, and I cannot help believing that the time will come when some good will arise out of it.

Obituary.

THE REV. JOHN IGNATIUS BLEASDALE, D.D.

Dr. Bleasdale was born in 1822, and was a native of Lancashire. At a very early age he was taken to Portugal, and his university training was obtained at an English College in Lisbon. In 1844 he returned to England and completed his studies at St. Mary's College, Oscott. He was ordained priest by the late Cardinal Wiseman, and for five years was garrison-chaplain at Weedon and Aylesbury. He came to Victoria in 1855, and was appointed vice-president of St. Patrick's College, where he taught experimental physics, having at an early age given his attention to this subject. He was also secretary to the Roman Catholic Archbishop. He joined the Royal Society of Victoria soon after its formation, and was for many years one of its prominent members, being in 1865 elected president. When in Portugal he had acquired an intimate knowledge of viticulture, and in the early days of wine-making in this colony he gave much valuable information on the subject, and read and published several papers of great practical importance on the wine industry. He had also an intimate knowledge of mineralogy, especially in the section of gem-stones, and he submitted frequent interesting communications thereon to this society. He was president of the first Intercolonial Exhibition in 1865, and ten years after he succeeded in procuring the establishment of a school of chemistry, assaying, and mineralogy in connection with the Public Museum, to the advancement of which institution he had steadily given his attention. He was elected in 1860 an honorary member of the Medical Society of Victoria, a distinction not until then conferred upon a non-medical man, and he occasionally read papers before that body having reference to his own special knowledge, but yet not uninteresting to the medical profession. Outside his sacerdotal duties he was well and widely known and much liked for his convivial qualities. About six years ago he left this colony for California, where he soon made himself known by the interest he showed in practical science and wine-producing. He died there about the middle of last year.

MR. WILLIAM GILLBEE, M.R.C.S., ENG.

DIED 4TH JANUARY, 1885.

MR. GILLBEE was a native of Hackney, near London, and was 60 years of age at the time of his death, which took place on the 4th of January of the present year (1885). His general education was conducted at Edinburgh, where also he attended the lectures on hospital practice qualifying him for examination by the London College of Surgeons, the diploma of which he obtained in 1848. He came to Australia in the following year, but did not then remain here, as he was attracted by the news of the gold discoveries in California, whither he repaired, and there remained two years, practising in the then unsettled mining communities of the very Far West. Returning to this part of the world, after experiencing somewhat romantic adventures both in the Pacific States and on board ship, he at once settled down in Melbourne, where he continued in the steady practice of his profession until the latter part of 1883, when his failing health induced him to visit the old country. In 1853 he was elected one of the surgeons of the Melbourne Hospital, an appointment he continued to hold for twenty-two years, and the duties of which he performed with singular fidelity. In 1855 he assisted in founding the Medical Society of Victoria, and in the same year he took a prominent part in bringing about the fusion of the Philosophical Society and the Victorian Institute, which conjointly became the Philosophical Institute, and afterwards, at a later period, the present Royal Society of Victoria. Mr. Gillbee was a member of the Council of the Royal Society for several years, and in 1864 was elected vice-president. In 1859 he was elected on the Exploration Committee, a body which had the onerous duty of directing the ill-fated Burke aad Wills Expedition. Although Mr. Gillbee was not a frequent contributor to the Transactions of this Society, he was for many years an active working member, and frequently took part in the discussions at the meetings.

In 1855 he helped to commence the *Australian Medical Journal*, a publication in which he took a warm interest, and to whose pages he was a steady contributor. In 1865 he helped to found the Medical Benevolent Association of Victoria; in 1879 he took part in establishing the Victorian Branch of the British Medical Association, of which he was chosen first President. He had in 1863 been the President of the Medical Society of Victoria. In 1853 he was one of about a dozen others who started the volunteer movement in this colony, and he eventually became Surgeon-Major of the Victorian Forces. In 1872 he was elected by a vote of the profession a member of the Medical Board of Victoria, of which, in 1878, he became President, a position he held until his death, which took place a few weeks after his return from England. He was an active and useful citizen, a good surgeon, and a genial companion.

MR. EDWARD DAVY, M.R.C.S.

Died January, 1885.

Edward Davy was born on June 6th, 1806, and received his education at a school kept by Mr. Bontflower, his maternal uncle. He was afterwards apprenticed to Mr. Wheeler, house surgeon at St. Bartholomew's Hospital, and about the year 1828 became a member of the Royal College of Surgeons, and soon after a member of the Society of Apothecaries. Shortly after this he bought a business at 390 Strand, London, and began to trade as an operative chemist under the name of Davy and Co. In 1836 he published a small work, entitled *Experimental Guide to Chemistry*; in this book he mentions several modifications of instruments he had invented, such as "Davy's Blow-pipe," and "Davy's Improved Mercurial Trough." In 1835 he invented and patented a cement for mending broken china and glass, which was known as "Davy's Diamond Cement," and it was about this time that he first experimented on the electric telegraph. His first telegraph necessitated the employment of 24 wires, insulated from each other, but he mentions that the number of wires might be reduced to six, owing to the numerous changes which could be made upon them by combination. The source of electricity was to be the prime conductor of a frictional electrical machine; the electricity was passed into the line by depressing keys suitably arranged. At the receiving end pith balls hanging in front of the letters of the alphabet were first attracted and then repelled from brass balls, to which the respective line wires were led, their discharge being effected by means of suitable earth connections. But this plan was not the one which Dr. Davy recommended to be put to practice; he merely described it to give a clearer insight into the principles involved. He very soon drew up a proposal for a telegraph based on the electro-magnetic properties of the voltaic current. This was to consist, like the former, of as many line wires as there were letters of the alphabet, but the number might be reduced by various combinations to which they would obviously be susceptible. He used a separate line for the alarm, and a common return wire. The ribbons or wires were to be all insulated and laid underground in a slight frame of well-varnished wood. In this telegraph, magnetic needles were to replace the pith balls, and were, on deflection by a current transmitted from the sending station through a small helix, to be caused to expose the particular letters intended to be signalled. The alarm was to consist of a small fulminate of silver caps, attached to a separate needle, which, on being deflected, dipped into the flame of a lamp and exploded. He soon saw that by employing reverse currents the number of wires might be reduced to one-half. Other very important improvements followed, enabling him at the commencement of 1837 to submit his apparatus to the test of actual experiment in Regent's Park, where, with the help of a friend, Mr. Grave, he performed many successful experiments. Becoming alarmed by hearing rumours that Professor Wheatstone was engaged on an electric telegraph, and in order to secure himself priority, he deposited with Mr. Aikin, the secretary of the Society of Arts, a sealed description of his invention in its then state. Davy then added the electrical renewer, or relay, which made his apparatus complete and practical. He had at this time most complete ideas of the capabilities of the electric telegraph, and the best mode of working the stations. A working model embodying all his improvements was shown November to December, 1837, at the Belgrave Institution, London, afterwards from December 29, 1837, to November 10, 1838, in Exeter Hall. He then invented a chemical recording telegraph, which he perfected before December 1837. He wished to take out a patent at once for this instrument, but, owing to the opposition of Cooke and Wheatstone, the specification was not sealed until July 4, 1838. In February 1838 he removed from 390 Strand to 199 Fleet-street, and for some time persistently endeavoured to get the public or the Great Western Railway Company to take the matter up. In 1839 he landed in South Australia, having during the years 1837 to 1838 frequently for private reasons intended leaving England. For the remainder of his life he resided in these colonies, busying himself in acclimatising trees, grasses, &c., the seeds of which he obtained in England. His leisure he filled up with writing newspaper articles on hygiene and other subjects. He also invented and patented "A plan for saving fuel during the process of smelting ores," and was Assay Master of the Melbourne Mint from 1853 to 1855. Davy then tried his hand at farming, and finally settled down at Malmsbury to practise his profession of surgeon. He was highly esteemed and respected in the district, and, to the great regret of all who knew him, died in January, 1885, at the age of 73. Not long prior to his death he had been elected an honorary member of this Society, and also of the Society of Telegraph Engineers, London, thus living long enough to see his claims as an inventor of the electric telegraph recognised both in England and in his adopted home.

He was one of the original founders of the Philosophical Institute of Victoria—one of the parent bodies afterwards merged in this Society—and contributed several papers to its Transactions.

JOHN FILE BAILEY.

Died June, 1884.

Mr. Bailey, who was one of the most successful and intelligent collectors of natural history specimens that we have ever had in Victoria, is deserving of remembrance by the scientific world in Australia for the contributions with which he enriched many of our public institutions. He had to contend against many difficulties when young, and all that he knew was acquired by the most honourable devotion to a life-long course of self-instruction. When a lad he served as signal-boy with the army at the Crimea, and it was there, on foreign shores, that his love of making collections of shells and fossils was first developed.

After coming to this colony he constantly filled up the leisure left him by a laborious and exacting business in the collection of specimens, and he was one of the most active and zealous workers in the ranks of the Field Naturalist Club.

He has rendered most material assistance to some of our leading scientific writers in the colonies, and their gratitude has found its usual mode of expression in the designation of species by the name of the collector. Purpura Bayleana, for instance, is figured in our own Transactions, Vol. XVII., p. 83. One of Mr. Bailey's most prominent discoveries was that of a fossil species of whale hitherto unknown, and described in Victorian *Palæontology* (Plate XLV., fig. 1, 2) under the name Physetodon Baileyi.

Mr. Bailey's death was occasioned by his devotion to his scientific pursuits. In the search for fossil remains in a newly opened bed in the rocks at Cheltenham, he entered the water and continued his researches while wet; the result being a chill which caused death in a few days.

1884.

PROCEEDINGS.

ROYAL SOCIETY OF VICTORIA.

ANNUAL MEETING.

March 12th, 1884.

Present, the President and 23 members and associates.

The Report and Balance-sheet for 1884 were read and adopted, as follow :—

"*Report of the Council of the Royal Society of Victoria for the Year 1884.*

"The termination of another year finds the Society in a position of great prosperity in so far as regards the number of Members and Associates, and its financial condition, but, unfortunately, your Council has to report that much less than the average of scientific activity has been displayed by its Members throughout the year. The number of papers contributed has been small, and although several of them are of very considerable importance to the progress of science in the colonies, the volume of Transactions will not, your Council regrets to say, exhibit the amount of work which might naturally be expected from so large a Society, including so many members of high scientific attainments.

"During the year there have been elected 12 new Members, 1 Corresponding Member, and 4 Associates.

"The Society now numbers 19 Life Members, 112 Ordinary Members, 36 Country Members, 7 Corresponding Members, 9 Honorary Members, and 71 Associates—making a total of 254 gentlemen belonging to the Society.

"Your Council regrets to announce the loss by death of the following Members and Associates—viz., Mr. W. C. Watts, Mr. J. F. Bailey, Rev. J. I. Bleasdale, Mr. W. Detmold, Mr. W. Gillbee, M.R.C.S., and Mr. E. Davy, M.R.C.S.

"During the year we have received for our library 64 volumes and 542 parts of scientific publications issued by learned and scientific bodies in all parts of the world, and in exchange have forwarded our annual volume of Transactions to 149 institutions of a similar character.

"Vol. XX. of the Society's Transactions was issued to Members in June, 1884. Vol. XXI. will be ready for distribution in April next.

"During the year, in addition to the Annual Conversazione, the Society held nine meetings, at which the following Papers were read:—

"March 13th.—Mr. G. S. Griffiths: 'On the Evidences of a Glacial Epoch in Victoria During Post-Miocene Times;' Mr. J. Stirling, F.L.S.: 'The Phanerogamia of the Mitta-Mitta Source Basin,' Part II.

"April 17th.—Hon. Dr. Wilkie: 'On the Determination of Small Circular Arcs by means of the Cycloid.'

"May 8th.—Mr. W. W. Culcheth, C.E.: 'Shingle on the East Coasts of New Zealand.'

"June 12th.—Mr. Lockhart Morton: 'Suggestions for the Reduction of Excessively High Temperature in Ships and Buildings;' Mr. G. H. Ridge: 'Experiences of the Barque 'W. H. Besse' in the Java Earthquake.'

"July 10th.—Mr. R. E. Joseph: 'Notes on Fire-Alarms;' Mr. MacGillivray, M.A., M.R.C.S.: 'Description of New, or Little Known, Polyzoa,' Part VII.

"August 14th.—Dr. Curl, F.L.S.: 'Cave Paintings in Australia;' Mr. T. Wakelin, B.A.: 'An Enquiry into the Cause of Gravitation.'

"November 20th. — Mr. MacGillivray, M.A., M.R.C.S.: 'Note on the Mode of Reproduction of the Ornithorhynchus;' 'Description of New, or Little Known, Polyzoa,' Part VIII.

"December 11th.—Mr. E. Davy, M.R.C.S.: 'On the Extinction of Waves at the Entrance of Harbours.' Mr. J. Stirling: 'Notes on the Meteorology of the Australian Alps.'

"DISCUSSIONS AND EXHIBITS.

"March 13th.—Professor Andrew opened a discussion on the Recent Red Sunsets.

"April 17th.—Discussion on Mr. Griffiths' paper, on 'The Evidences of a Glacial Epoch in Victoria during Post-Miocene Times.' Mr. P. Behrendt exhibited a Telemeter.

"May 8th.—Mr. Ellery opened a discussion on some showers that had recently fallen stained with mud; Professor Andrew exhibited and explained to the meeting a new method of inducing a charge in the Electroscope, with less trouble than is necessary in the ordinary way.

"July 10th.—Professor Kernot exhibited some harmonic curves produced by a compound pendulum constructed by Mr. Russell, the Government Astronomer of New South Wales; Mr. Ellery read an abstract of a report by Mr. Verbeek on the Krakatoa eruption, translated by Jonkheer Ploos van Amstel.

"October 16th.—Mr. Ellery opened a discussion on the probable effect of the removal of the falls of the Yarra on the water used for the Botanic Gardens.

"*Report of Section A.*

"During the year 1884 eleven meetings were held. The attendance at the meetings and the interest taken in the work has been very encouraging. The chief local event which came under notice of the Section was the Engineers' Exhibition, under the auspices of the Engineers' Association, which furnished many interesting topics for discussion.

"The papers read and discussed gave evidence of careful thought and accurate observation on the part of the Members.

"The following is a list of the chief papers which were discussed:—

"'Underground Telegraphs.' Mr. J. H. Fraser, C.E.

"'The Strength of Timber.' Mr. G. R. B. Steane, C.E.

"'The Web of Plate Girders.' Mr. J. H. Fraser, C.E.

"'Indicator Diagrams.' Mr. C. W. M'Lean, C.E.

"'Speed Regulators.' Mr. J. Booth, C.E.

"'The Strength of Cast and Wrought Iron Beams.' Mr. J. H. Fraser, C.E.

"'Accurate Chainage.' Mr. Steane.

"'Boiler Explosions.' Professor Kernot.

"B. A. SMITH, *Hon. Sec.*"

BALANCE-SHEET.

The Hon. Treasurer in Account with the Royal Society of Victoria.

Dr.

To Balance from last Balance-sheet		£308 3 4
„ Government Grant—Balance of 1883-84 ...		50 0 0
„ Do. do. portion of 1884-5 ...		85 0 0
„ Eight Entrance Fees		16 16 0
„ Subscriptions—		
1 Life Member	£21 0 0	
70 Members	147 0 0	
4 do. (Half-years) ...	4 4 0	
25 Country Members	26 5 0	
48 Associates	50 8 0	
3 do. (Half-years) ...	1 11 6	
Arrears	27 6 0	
Commission	0 2 6	
		277 17 0
„ Rent and Gas		7 13 4
„ Sale of Transactions		0 14 0
„ Interest		13 13 0
		£759 16 8

Cr.

By Printing and Stationery	£97 16 6
„ Furniture	8 5 0
„ Books	2 2 0
„ Binding	38 6 0
„ Freight and Charges of Books and Transactions ...	6 16 11
„ Conversazione and Teas	16 14 10
„ Rates	4 13 4
„ Gas and Fuel	5 17 10
„ Repairs, &c.	24 12 2
„ Clerical Assistant	36 0 0
„ Hall-keeper	6 0 0
„ Collector	31 18 11
„ Insurance	3 10 0
„ Postage	26 14 5
„ Petty Cash, Advertising, and Sundries	3 11 0
	£312 18 11
„ Balance in Bank	446 17 9
	£759 16 8

Compared with the Vouchers, Bank Pass-book, and Cash Book, and found correct.

25th February, 1885.

H. MOORS, Hon. Treasurer.

JAMES E. GILBERT }
R. E. JOSEPH } Auditors.

STATEMENT OF LIABILITIES AND ASSETS.

Dr. LIABILITIES.	£	s.	d.	ASSETS. Cr.	£	s.	d.
To Three Debentures outstanding	£15	0	0	By Estimated Value of Outstanding Subscriptions ...	£40	0	0
,, Interest unclaimed	12	12	0	,, do. do. Rents due	5	0	0
,, Estimated Amount of other Outstanding Liabilities	26	0	0	,, Hall, Library, Furniture	3500	0	0
	£53	12	0	,, Balance in Bank	446	17	9
,, Balance	3938	5	9				
	£3991	17	9		£3991	17	9

March 13*th*, 1884.

Present, the President (in the chair) and 40 members and associates.

Professor Andrew read a note on "The Red Sunsets," in which he explained the principle according to which the fine dust, supposed by some to be the cause of these phenomena, might float in the upper regions of the atmosphere without showing any tendency to descend. He said that Mr. Ellery had raised a difficulty in connection with one of the theories that had been propounded to account for the remarkable afterglows which created so much public interest, to the effect that if they had been due to the suspension of fine particles of volcanic or meteoric dust, they would have ceased long ago, as the particles would be quickly precipitated. The theory that the red sunsets were due to the presence of particles in the air would naturally lead any thinking person to ask how it was possible that particles specifically heavier than the air could remain for a long time in the atmosphere? Three theories had been propounded to account for the remarkable afterglows, and from those three were two offshoots. The theory which Mr. Ellery announced was, that the red glow after sundown was due to the accumulation of an unusual quantity of aqueous vapour in the upper regions of the atmosphere. That theory had received the support of the President's colleague, Mr. Russell, Government Astronomer, Sydney, and of Professor Michie Smith, of Madras College, who attributed the peculiar green colour of the sun and moon, which had been observed in India, to the presence of aqueous vapour in the atmosphere. The second theory was that the earth at present is, and had for some time past been passing through a band or zone of meteoric dust; and the third theory attributed the afterglow to the distribution in the atmosphere of volcanic dust, consequent on the explosion at Krakatoa. The two offshoot theories were—(1) a combination of the first and third, and (2) a combination of the second and third. The only modes of testing the truth of these theories was the use of the spectroscope and the actual production of dust precipitated from the atmosphere. His own observations, made with an inferior instrument, and without actual measurements, led him to agree with those made much more carefully by Mr. Ellery; but the fact that in Holland there had been falls of rain impregnated with black dust, and in Spain falls of snow similarly impregnated, and that this dust was found on careful analysis to be identical with that brought from the scene of disaster, rendered the evidence from the two sources antagonistic. The volcanic-dust theory was most generally adopted at home, though with very great diffidence; but no scientific man of any eminence had ventured to say that the problem had been solved with any certainty; indeed, Professor

Piazzi Smith was of opinion that some years must elapse before it would be possible to arrive at any definite conclusion, and he suggested a more careful analysis of the constitution of the very high strata of the atmosphere than had hitherto been made. Of the theories put forward, certainly three of them required for their complete establishment the removal of the one difficulty which had been raised by Mr. Ellery as to the precipitation of the dust. Some very curious theories had been started to account for the suspension in the atmosphere of meteoric or volcanic dust. Preece was said to have suggested that the particles were similarly electrified, so that by mutual repulsion they were maintained at a high altitude. Professor Andrew then proceeded to prove from dynamical principles that the suspension in the atmosphere, for long periods, of particles of dust specifically heavier than the air was not incompatible with known dynamical laws.

The President said that there were instances of the extraordinary afterglow and of a green sun noticed prior to the Krakatoa eruption, and he reminded the members of the Society of the great aurora of 1869, when at 10 o'clock on a moonless night one could read the newspaper by the red light of the aurora, which was far more intense than even the recent remarkable sunsets. He did not think the volcanic dust found in Spain and Holland proved anything more than that it had probably been thrown up into the air by the explosion at Krakatoa, and had fallen in the countries named. But that did not, in his opinion, account for the peculiar sunsets. The theory that we were passing through a region of cosmic dust was equally possible, but very improbable, considering, from the time the afterglows have continued, that we must have passed through a belt 180,000,000 miles in thickness, and are still in it, the sunset that evening being as beautiful as any we have had. He believed it would yet be found that water, in some form, had played the principal part in the sunsets. He had had another idea, but it was more of a speculation than a theory. At the time of the Krakatoa earthquake there was noticed all round the world a peculiar disturbance of all the barometers, repeated at certain intervals for several days after the explosion, and he could imagine that a terrific blow by the lower to the more elastic portion of the upper atmosphere had given a kind of shudder round the earth, disturbing the whole region of the upper atmosphere, the upper air having a kind of shiver, so to speak. If it were admitted that such a thing was possible—and they must admit also, as chemists, that there are states of matters, compounds and mixtures, combinations, and so forth, where they are in a state of equilibrium, just on the verge of combining or breaking up—a shock like that would cause a total alteration of the physical character of the mixture or matter on which it was effected. Now, if they could suppose that the upper portion of the earth's atmosphere were so loosely combined as to be altered in its constitution by a shiver of that kind, it would perhaps be a tenable theory that those red sunsets may have been caused by some alteration of the upper region of the air from that cause. It was only a hypothesis, but the barometric disturbances were so universally felt, and were so terrific, that something of the kind he now suggested might easily be conceived as possible. He believed we should have to wait for the true theory. He certainly could not accept the dust theory, because he could not explain how it was possible that the dust could have been so universally diffused as to bring about the phenomena that had been observed in various parts of the world.

Professor Kernot pointed out, in support of the observations of Professor Andrew as to the suspension in the air for a long time of particles specifically heavier than the atmosphere, that to test its accuracy one had only to observe the floating particles revealed by admitting a ray of sunlight into a darkened room.

The President said he had lately received some fresh reports, one or two of which were rather curious. A gentleman in his garden at Urana, New South Wales, wrote to say that during one of the wonderful afterglows it became so suddenly dark, although the red glow remained, that he had to put down his watering-pot. Then there was a sudden accession of light, a quarter of an hour of twilight; and these pulsations of light occurred at intervals lasting each time for a considerable period. In the Western District, on one occasion, the beautiful rose-coloured light was seen bounded by an intensely black band, defining the margin with great distinctness.

Mr. Griffiths read his paper on "The Evidences of a Glacial Epoch in Victoria during Post-Miocene Times."

Mr. James Stirling read his paper on "The Phanerogamia of the Mitta-Mitta Source Basin."

April 17*th*, 1884.

Present, the President (in the chair) and 21 members and associates.

Captain Wagemann was elected a member, Dr. Wagner a corresponding member, and Mr. Ludovic Hart an associate of the Society.

A discussion took place on the paper read by Mr. Griffiths at the previous meeting. Mr. Ellery, Professor Kernot, and Mr. Rosales mentioned a number of facts which seemed to support Mr. Griffiths' views as to the existence of a glacial epoch in Victoria during comparatively recent geologic times. Mr. Selby and

Mr. Sutherland supported the views enunciated in the paper, as to the probability that the recurrence of glacial epochs is to be explained on Dr. Croll's theory by the combined effects of the precession of the equinoxes and of the variation in the eccentricity of the earth's orbit.

A paper by the Hon. Dr. Wilkie, "On the Determination of Small Circular Arcs by means of the Cycloid," was taken as read.

May 8th, 1884.

Present, the President (in the chair), 27 members and associates.

Mr. James Chapman, C.E., was elected a member, and Mr. Francis O. Hill as an associate, of the Society.

Mr. Ellery exhibited some specimens of mud which had recently fallen in various parts of the colony as rain-showers.

Mr. Newbery said he had examined some of this mud which had been submitted to him for inspection, and found it to consist of powdered basalt and organic matter, such as would be swept off the roads by the wind. He had no doubt but that the prevailing dust storms had carried up into the higher regions of air great quantities of finely pulverised matter, and that this had been brought down by a shower of rain to such an extent as to colour the raindrops, and give them the appearance of mud.

Professor Andrew explained to the Society a little point in connection with the charging of an electroscope. All that was necessary was merely to rub the knob of the instrument, thus doing away with the use of an electrophorus every time the instrument was to be employed.

Mr. Culcheth read his paper on "Shingle on the East Coasts of New Zealand."

A discussion followed on the means of keeping natural and artificial harbours clear of shingle.

June 12th, 1884.

Present, the President (in the chair) and 17 members and associates.

Mr. A. M'Petrie, Mr. W. H. O. Smeaton, and Mr. J. S. Wilson were elected members of the Society.

One of the Honorary Secretaries read a paper by Mr. Lockhart Morton, entitled "Suggestions for the Reduction of Excessively High Temperatures in Ships and Buildings."

A discussion ensued, in which Mr. Griffiths stated that this very principle advocated by Mr. L. Morton had been applied in the case of a vessel recently built. Mr. Ellery stated that the idea proposed was perfectly practicable, and that there was much room for something of this sort in the management of hospitals in this hot climate.

Mr. Ridge read a paper entitled "Experiences of the Barque 'W. H. Besse' in the Java Earthquake."

In connection with this paper Mr. Ellery read some interesting memoranda from the meteorological observers of the northern parts of Western Australia, showing the effect of the Java earthquake on the tides and barometers of that colony.

July 10*th*, 1884.

Present, the President (in the chair) and 27 members and associates.

Mr. A. C. Smith was elected an associate of the Society.

Dr. MacGillivray's paper on "New or Little Known Polyzoa," Part VII., was taken as read.

Mr. Verbeek's report on the Krakatoa earthquake was read by the President, as translated by Mr. Ploos van Amstel. The thanks of the Society were directed to be conveyed to Mr. Van Amstel.

The President read a letter from Messrs. Hughes, Pye & Rigby, in which they stated that the compressed-air principle for cooling ships and buildings, as suggested at the last meeting by Mr. Lockhart Morton, had been applied by them, some time previously, on board the s.s. "You Yangs."

Mr. Joseph read his paper on "Fire Alarms."

Professor Kernot showed some harmonic curves produced by a compound pendulum, the property of Mr. Russell, of Sydney.

Special Meeting, August 14*th*, 1884.

Present, the President (in the chair) and 38 members and associates.

The President stated that the meeting was called in order to devise some means of organising a subscription to raise a testimonial to Dr. Davy, of Malmsbury, who was now allowed on all sides to have been one of the chief workers in the early development of the electric telegraph.

Professor Kernot said that he was one of the committee appointed to inquire into the merits of Dr. Davy's work in connection with the discovery and development of the electric telegraph. It would be an invidious and indeed impossible task to arrange in order of merit the names of the early workers in this direction. But he thought there could be no doubt that Dr. Davy's name could deservedly take its place among those of the founders of the electric telegraph.

Mr. M'Gowan said he had the honour of intimate acquaintance with Dr. Davy, and he could attest, from his own personal knowledge, that the relay instrument, invented and constructed by Dr. Davy nearly fifty years ago, was identical in principle with that now universally used.

Mr. Selby said that, having studied the history of the early development of the electric telegraph, he was quite certain that Dr. Davy had every claim to be considered one of the founders of the telegraph.

Mr. Bosisto moved, and Mr. Rosales seconded, the following motion, which was unanimously adopted:—"That the Royal Society, being assured of Dr. Davy's claims to consideration as one of the inventors of the electric telegraph, resolves to do all in its power to secure the recognition of his services."

Mr. Sutherland moved, and Mr. Macdonald seconded, the following resolution, which was adopted unanimously:—"That the President, the Vice-Presidents, Mr. Bosisto, Mr. M'Gowan, Mr. Blackett, Mr. Newbery, and Mr. Selby be asked to form a deputation to the Premier to urge the claims of Dr. Davy on the Government of Victoria."

Mr. Sutherland moved, and Mr. White seconded, the following resolution, which was carried unanimously:—"That a subscription list be opened for the purpose of presenting a testimonial to Dr. Davy, and that the Council of the Society be empowered to grant a sum not exceeding £50 with which to head the list."

The meeting then resolved itself into an ordinary meeting of the Society, when the librarian reported the receipt of 26 volumes and 192 parts during the past three months.

Mr. Johnston Hicks and the Hon. W. M. K. Vale were elected members.

A paper by Dr. Curl, of New Zealand, was read, in which he endeavoured to prove that the drawings and inscriptions found by Captain Grey in caves in Western Australia are of Phœnician origin. He considered that the marks as given in Captain Grey's volumes are sufficiently close in appearance to some of the Syrian alphabets to warrant the translation, "I am Goliath," and that the figure is in many respects in keeping with such an origin.

A vote of thanks was passed to Dr. Curl for his paper, and the secretaries were directed to refer it to Mr. Andrew Harper, M.A., for his opinion as to the correctness of the views it contained in regard to the alleged resemblance of the inscriptions to the letters of the Syrian alphabet.

October 16th, 1884.

Present, the President and 11 members and associates.

There being no quorum, the election of gentlemen nominated for membership was postponed till next meeting.

The President stated that at the last Council meeting of the Society the sum of twenty guineas had been voted to Dr. Davy, and that subscriptions would be received by Mr. Selby towards the proposed testimonial.

Mr. Howitt's paper, on "The Diabase Rocks of the Buchan District," was taken as read, and ordered to be printed.

The President made some rémarks on the probable effects that would follow the removal of the obstructions in the river at the place known as the "Falls." He considered that the Botanic Gardens, which depended for their supplies of water on the river, would suffer severely.

Professor Kernot remarked on the want of proper gauging of the volume of water delivered by the Yarra, and gave the result of numerous observations of his own.

November 20th, 1884.

Present, the President (in the chair), 18 members and associates.

The President stated that he had received from the Society of Electric Telegraph Engineers a telegram stating that Dr. Davy had been unanimously elected an honorary member of that Society.

The following gentlemen were duly elected :—Mr. Hubbard, as a member ; Mr. Bruce Smith, as a member ; Mr. J. A. Springhall, as a member ; Mr. A. Newham, B.A., as an associate.

Two papers by Dr. MacGillivray were then read, entitled "The Mode of Reproduction of the Monotremata ;" and "New or Little Known Polyzoa," Part VIII.

In connection with the former paper he exhibited five fine specimens from the female Ornithorhynchus, showing the uterus, ovaries, and mammæ of these animals.

A discussion arose as to the significance of certain apparent attachments, Dr. MacGillivray considering them as indicating a rudimentary placenta, Dr. Jamieson being disposed to dispute that interpretation.

December 11th, 1884.

Present, the President (in the chair), 13 members and associates.

Mr. A. A. Lucas was elected a member. Mr. Donald Manson was elected a member.

A letter was read from Dr. Davy, of Malmsbury, on the "Extinction of Waves at the Entrance of Harbours." Mr. Davy's proposal was to moor floating bodies, which, being unable to rise with the waves, would reduce the volume of the wave when it had passed them. With two or three series of these floating bodies, Mr. Davy thought that the interior of harbours might be rendered perfectly safe.

A discussion ensued, in which it was asserted that the impossibility of mooring large bodies to the rocks at the bottom of the sea, so as to withstand the momentum of great waves, would be an insuperable obstacle.

Mr. Stirling read a paper on the "Meteorology of the Australian Alps."

A discussion ensued, in which some peculiarities of climate in the Australian Alps were noticed, particularly a fact stated by Mr. Ellery to be of frequent occurrence—the higher temperature of the higher portions of mountain valleys. It seems that crops, such as potatoes, are often killed by the cold in the lower part of the valleys, while they sometimes thrive well half-way up the hill-sides overlooking the same valleys.

ABSTRACT OF PROCEEDINGS OF SECTION A.

February 27th, 1884.

Mr. J. H. Fraser read a paper on "Underground Telegraphs."

He pointed out the dangers arising from aërial lines, and contended that, as the underground system is being extensively used in Europe with satisfactory results, we should lose no time in adopting it in this country.

One great advantage of underground telegraphs is immunity from thunderstorms.

During the course of his remarks Mr. Fraser exhibited several pieces of cables of the kind in common use, and pointed out their various advantages. One of the best is the Patterson Cable, in which about fifty insulated wires, surrounding a return wire, are enclosed in a lead pipe. The great difficulty hitherto has been to exclude moisture; this is fairly well done in the Patterson Cable by forcing paraffin oil and carbonic dioxide into the pipes by heavy pressure.

As to the distribution of the wires, Mr. Fraser suggests that main cables should be laid along the principal streets in such a way as to divide the area supplied into rectangular sections, one for each main cable, and then to subdivide this into small rectangles by means of the several bundles of wires of which the main cable is composed. Each of these small sections would be supplied by the individual wires of the bundles.

March 26*th*, 1884.

Mr. G. R. B. Steane read a paper on "Timber."

A piece of timber may fail in many ways, *e.g.*, by tension, detrusion, shearing, direct crushing, as in a short block; crushing and flexure, as in struts of medium length; and pure flexure, as in long columns.

It is essential that we should know the limits of strength and elasticity. Up to the elastic limit it is found that the elasticity is approximately equal in tension and compression, but beyond that limit this is no longer the case. This is probably the reason of the very remarkable behaviour of beams of every material when approaching their breaking load.

In the conduct of experiments on timber but little care is usually bestowed on the selection of suitable pieces for testing. The pieces tested are usually of small size, and in this case the various apparent strengths are invariably too high.

With regard to factors of safety, the question arises, "Should we use the same factor for all timber structures, as some writers seem to imply?" He thought not, for some timbers are more reliable than others, and it is only by numerous and very careful observations on the behaviour of any kind of timber that we can come to any satisfactory determination of its proper factor of safety.

In the discussion which followed Mr. Steane's paper arose the important question of cheap flood-openings.

The ordinary culverts and small timber bridges to be seen in the colonies show great diversity of practice.

In one of the colonies the bridges for a single line narrow-gauge railway are 15 feet wide, and decked all across; and one rather important bridge has an open space in the centre, and is decked at the sides.

Timber railway bridges should never be built on the skew; for, in that case, part of the weight of the engine comes on a rigid pile, and another part on a yielding beam, causing the engine to roll.

A very cheap form is that used on the Victorian light lines, 10 or 11 feet spans, with planks 7 inches square section, going over two spans and breaking joint over each. Ballast is laid over the whole deck, and sleepers put on it as on the earth formation.

The comparative cost of a few types of single-line railway bridges is :—

Strutted Bridges ...		...	£4 10s.	per foot rise
Timber ,, ...		...	6 0	,, ,,
Iron ,, ...		...	50 0	,, ,,
Yankee Cobweb	Timber	...	24 0	,, ,,
	Iron	...	35 0	,, ,,

April 30*th*, 1884.

Mr. Fraser read a paper on "The Web of Plate Girders," a subject which has attracted very slight attention from scientific men, but which, from its theoretical interest and practical importance, is worthy of close study.

The function of the web is to carry the weight of the load on the girder to the abutments, hence every element must be acted on by two internal inclined forces; a tension directed along a line sloping upwards and outwards, and a compression downwards and outwards. It has been usual to design the web as if it were a column merely under the action of the compression, quite ignoring (except, perhaps, by implication) the assistance which it receives from the lines of tension crossing those of the compression.

Now, in an open girder loaded on the bottom member, when a tension diagonal crosses a compression diagonal the stress in the tie is always greater than that in the strut. Hence, treating the web girder as a limiting case of an open girder, in which the number of diagonals is indefinitely increased and their distance indefinitely diminished, it follows that the same statement must apply to a web girder.

Therefore any tendency of the web to bulge to either side on account of the compression will be overcome by the tendency, exerted by the tension in the web, to keep it in one plane, so that the web cannot fail in this way.

But if the web tend to crumple under the compression, the tendency to straighten under the tension is less than the tendency to further crumple, so that the web would fail.

In order to prevent this crumpling, stiffeners are introduced. But from what we have seen above, it follows that these need only be of the very lightest angle iron, say $2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$, and on one side only of the web. An apparent exception is over the bed plate, but in this place the ∠ irons do not act as stiffeners, but as true struts, and must be made accordingly. As a rule, the stiffeners should be inclined downwards, and outwards at an angle of 45°.

In the discussion which followed, Professor Kernot mentioned that, as a general rule, he was averse to spreading the metal in the form of thin plates, as is done in web girders, on account of corrosion, but in some cases their use is unavoidable. From a series of experiments on cardboard models, he has come to the conclusion that their behaviour is very different when loaded on the top and on the bottom member; but he is not aware of any difference of construction in the two cases. Further discussion was postponed till next meeting.

Mr. Behrendt then exhibited a telemeter, a new instrument to serve the purpose of a stadiometer, but on a base of only 18 inches in length. The inventor claims that the error in measuring a length of 1000 yards is less than two feet.

From a series of careful experiments, carried out under the superintendence of Mr. A. C. Allan, who has had considerable experience in careful observation while carrying out the geodetic survey of this colony, it appears that at so short a distance as 15 chains the instrument cannot be depended on to within 10 or 15 feet.

At a distance of 1000 feet an error of one second in the measurement of the angle, subtended by a distance of 18 inches, is equivalent to an error in the apparent distance of the object of over three feet. So that very accurate results can hardly be looked for.

Professor Kernot showed some photographs of the Tay Bridge, and some of the rolling stock, taken after the accident. Then followed a few words about the bridge, the cause of the accident, and a general discussion on the "Factors of Safety" to be used for wind pressure.

May 21*st*, 1884.

Mr. Behrendt opened the discussion on Mr. Fraser's paper.

He pointed out concisely the action of a load, distributed in any manner, on a beam; giving the mathematical expression for the various results. Though no English work contains any examination of the web stresses, yet the subject is very fully considered in many German works, a few of which Mr. Behrendt mentioned.

Professor Kernot pointed out the desirability of experimenting on models; these should be of iron rather than paper, since paper has no lateral stiffness to resist the crumpling action.

Several members joined in the discussion.

June 25*th*, 1884.

A paper was read giving a brief description of a visit to a coal mine at Kilcunda.

Mr. M'Lean then read a paper on "Some Remarkable Indicator Diagrams." They were taken from the compound engine of the dredge "Crocodile."

This engine had been designed heavy enough to bring the dredge out from England, and hence it was much too heavy for the ordinary work of dredging. Again, it is subjected to very varying resistances, according to the material cut out by the buckets, so that the horse-power required from it may vary within very wide limit.

The most curious result was obtained with light load and boiler pressure 50-lb., engines making 60 revolutions per minute. In the high-pressure cylinder the maximum pressure was 24 lbs., while the minimum was actually 3 lbs. below atmosphere. In the low pressure the maximum pressure was 3 lbs., and the minimum 12 lbs., giving about one-quarter work of high-pressure cylinder.

With higher boiler pressure, and the engine more heavily loaded, the diagrams are of the normal form for compound engines.

The "Crocodile" has two boilers, and the consumption of fuel with one and two boilers at work deserves notice.

Under ordinary conditions, Mr. M'Lean found it more economical to use one boiler with a good fire than to use both even with a very slow fire.

But when the engines are heavily loaded, so that one boiler would require to be forced, he found that the two with ordinary fires gave better results.

July 27*th*, 1884.

Mr. Booth read a paper on "Speed Regulators."

He divides speed regulators into three classes:—(1) Those which use up none of the driving power, but simply store energy, as the fly-wheel. (2) Using a small fraction of the driving power in regulating the speed of the engine, such as ordinary governors. (3) Those in which regular speed is essential, and to attain which we can use up all the driving power; such are astronomical pendulums of various kinds.

The incandescent light is, perhaps, the most delicate test of speed which we commonly meet; eight per cent. variation in speed makes all the difference between full on and quite out.

The chief causes of inaccuracy in governors of the second class, and the methods to be used in order to overcome them, would seem to be—

(1.) The steam between the governor and the piston is beyond the control of the governor. To remedy this, we must make this distance as short as possible.

(2.) Irregularity in driving power and resistance. This is the great difficulty which the governor has to overcome. Perhaps the most we can do is to assist the governor as much as possible by making the fly-wheel much larger than is usually done.

(3.) Loss of time in the governor, arising from friction, &c. We should therefore relieve it from as much work as possible. In this respect, the gas-engine governors are the best with which we are yet acquainted.

(4.) The governor is not isochronous.

This may be corrected, very approximately, by giving the arms a short range, and using a high-speed governor.

Where a very delicate governor is required, Mr. Booth advocates the use of a combination of the Cross-arm and Porter governor, having a very small range, which may be attained by using the gas-engine link motion to regulate the supply of steam.

It will be noticed that this form possesses all the necessary qualities mentioned above.

A short discussion followed, most of those present agreeing with Mr. Booth's views.

Professor Kernot then laid Mr. Mais' report on the table.

August 27th, 1884.

Mr. Steane gave the dimensions of the new girders, and details of the sizes of iron used, at the Victoria-street Bridge. After going rapidly through the calculations of the stresses on the various parts, a conclusion was arrived at, that these girders do not seem to have been designed in accordance with the result of accurate calculation.

October 1st, 1884.

Mr. Fraser read a paper on "The Sources of Unexplained Strength in Cast and Wrought Iron Beams."

In all physical investigations it may be taken as an axiom, that we must introduce no new law to account for an apparent anomaly, until we have made a complete examination of all aspects of the case in the light of laws already known, and still fail to account for the peculiar case.

This remark applies very directly to the case under notice, but it seems to have been quite neglected by the chief authorities on the strength of beams, with the result that what is really a simple consequence of two facts to be presently mentioned, is looked on as an obscure anomaly.

The ordinary formula for the moment of resistance of a rectangular beam ($\frac{1}{6} f b h^2$), rests on two assumptions—

1. That elasticity is equal in tension and compression.
2. That elasticity is constant up to breakage.

Neither of these is strictly correct, though both are approximately true till near breaking load.

In cast-iron beams the formula gives strength only 40 per cent. of the truth; and in wrought-iron, only 60 per cent.

To correct this, it is usual to increase f to $f + \Phi$, Φ being arranged to make results agree with experiment.

This empirical formula gives results very closely in accord with experiment, but throws no light whatever on the source of the extra strength.

To account for this strength, we need only examine the effect of the variations in the elasticity—

(1). Suppose elasticity constant up to breakage, and equal in tension and compression, then the neutral axis will be at the centre of the beam, and the stress will vary uniformly over the section. In this case we shall have the formula ($\frac{1}{6} f b h^2$) rigorously exact.

(2). Suppose the modulus of elasticity decreases slowly with the stress, but is equal in tension and compression, then the neutral axis will be at the centre; but the stress at any point increases in a less ratio than the distance of the point from the neutral axis, so that the stress-curve bulges and the beam is slightly stronger than appears from the formula.

(3). Suppose the modulus of elasticity is greater in compression than in tension, and that elasticity varies with the stress, then the neutral axis will rise above the centre of the beam, and the curves bulge considerably, then the beam will fail by compression, but will be considerably stronger than appears from the formula. This is the case with cast iron. With wrought iron the modulus of elasticity is less in compression, so that the neutral axis falls and the beam fails in tension; but as the difference between the two elasticities is not so marked as in cast iron, the discrepancy from the formula is not so great.

26th November, 1884.

Professor Kernot brought up the subject of the Richmond boiler explosion of the 7th inst. This was a Cornish boiler, 14 feet 2 inch x 4 feet 10 inch, $\frac{5}{16}$-inch thick; end plate, $\frac{3}{8}$-inch. No stay pieces were used. The angle irons used at the ends were of very poor quality, $2\frac{1}{2}$ inch x $2\frac{1}{2}$ inch x $\frac{1}{4}$ inch, having a square instead of a rounded internal angle. Boiler pressure was usually 50 lbs. per square inch. Fracture took place by the back end of the boiler separating completely from the shell, which shot out like a rocket across the street. The cause of the explosion seems to have been the bulging of the ends; this split the angle irons at one end completely, and then came the explosion.

Passing on from this particular case, Professor Kernot gave some information on the subject of the design of boilers.

In all boiler questions there are three important questions of strength—

1. As against bursting;
2. As against collapsing;
3. As against ends failing;

of which the last is by far the most difficult to deal with.

The chief authorities on the subject are Wilson on Boilers, The Board of Trade, and the classical experiment of the Manchester Steam Users, described in *Engineering* of May, 1876.

Wilson says, a $\frac{3}{8}$-inch plate for working pressure of 50 lbs. per square inch should be supported at $8\frac{1}{2}$-inch intervals. Board of Trade says at 10-inch intervals. The Richmond boiler was $23\frac{1}{2}$ inches in one place, so that one could never have called it a safe boiler.

Professor Kernot mentioned that it has been his experience that explosions occur not so much from hidden causes as from very simple ones. The explanation invariably is exceedingly bad design or culpable negligence on the part of the man in charge.

The question of factors of safety was raised. In answer to this, Professor Kernot gave the instructions of the Board of Trade:—"For boilers, in accordance with their design, the working pressure must not exceed one-fifth of the calculated bursting pressure, and the testing pressure must be two-fifths the calculated bursting pressure."

In testing a second-hand boiler, Mr. M'Lean stated that he simply tests it to one-third more than the working pressure, so as not to overstrain it.

Locomotive boilers are worked to 130 lbs., and tested to 180 lbs.

Mr. M'Lean described a new form of diaphragm pressure gauge, which gives very accurate results.

The meetings then closed for the year, to recommence after the recess.

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Royal Society of Arts	London
Royal Geographical Society	London
Royal Asiatic Society	London
Royal Astronomical Society	London
Royal College of Physicians	London
Royal Microscopical Society	London
Statistical Society	London
Institute of Civil Engineers	London
Institute of Naval Architects	London
The British Museum	London
The Geological Society	London
Museum of Economic Geology	London
Meteorological Society	London
Anthropological Institute	London
Linnæan Society	London
Royal College of Surgeons	London
Zoological Society	London
"Athenæum"	London
"Electrician"	London
"Geological Magazine"	London
"Quarterly Journal of Science"	London
"Nature"	London
Colonial Office Library	London
Foreign Office Library	London
Agent-General of Victoria	London
Natural History Museum	South Kensington
University Library	Cambridge
Philosophical Society	Cambridge
The Bodleian Library	Oxford
Public Library	Liverpool
Literary and Philosophical Society of Liverpool	Liverpool
Owen's College Library	Manchester
Free Public Library	Manchester
Literary and Philosophical Society	Manchester
Yorkshire College of Science	Leeds
Institute of Mining and Mechanical Engineers,	Newcastle-on-Tyne

Royal Society	Edinburgh
University Library	Edinburgh
Royal Botanic Garden	Edinburgh
Royal Physical Society	Edinburgh
Royal Scottish Society of Arts	Edinburgh
Geological Society	Edinburgh
Philosophical Society	Glasgow
University Library	Glasgow
Institute of Engineers of Scotland	Glasgow
Naturalists' Society	Bristol
Royal Irish Academy	Dublin
Trinity College Library	Dublin
Royal Geological Society of Ireland	Dublin
Royal Dublin Society	Dublin

EUROPEAN.

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Acclimatisation Society	Paris
Royal Academy of Sciences	Brussels
Royal Geographical Society	Copenhagen
Royal Danish Society of Sciences	Copenhagen
Academy of Science	Stockholm
Royal Academy of Sciences	Upsal
The University	Christiania
Imperial Academy	St. Petersburg
Geographical Society	St. Petersburg
Imperial Society of Naturalists	Moscow
"Petermann's Geological Journal"	Hamburgh
Society of Naturalists	Hamburgh
Royal Institution	Utrecht
Royal Netherlands Meteorological Society	Utrecht
Royal Academy of Science	Amsterdam
Geological Society	Darmstadt
Linnæan Society	Darmstadt
Academy of Natural History	Giessen
Geographical Society	Frankfort-on-Main
Royal Academy of Science	Munich
Royal Academy	Vienna
Royal Geological Society	Vienna
Royal Geographical Society	Vienna
Royal Botanical Society	Ratisbon
Imperial Academy	Breslau
Society for Culture of Science	Breslau
Royal Society of Sciences	Leipzig
Royal Society	Berlin
Geographical Society	Berlin

Ornithological Society	Vienna
Royal Academy of Petrarch for Sciences	Arezzo
Imperial Leopoldian Carolinian Academy of German Naturalists	Halle
Society of Sciences of Finland	Helsingfors
Society of Naturalists	Halle
Physico-Graphico Society	Lund
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Natural History Society	Geneva
Royal Academy of Science	Madrid
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Geographical Society	Lisbon
Society for Culture of Science	Bremen
Royal Academy of Agriculture	Florence
Italian Geographical Society	Florence
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Minister of Public Works	Rome

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Philosophical Society of Sciences	Washington
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Department of the Interior	Washington
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"Science" ... ... Cambridge, Mass.
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Meteorological Society ... ... Mauritius
Royal Society of Natural Sciences in Netherlands India Batavia
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German Association ... ... Melbourne
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ANNIVERSARY ADDRESS

OF

The President,

PROFESSOR KERNOT, M.A.

(Delivered to the Members of the Royal Society of Victoria, at their Annual Conversazione, held March 11th, 1886.)

GENTLEMEN OF THE ROYAL SOCIETY,

My presence upon this platform to-night is an evidence to you that a great change has taken place in our Society. For nearly twenty years past you have been in the habit of listening, upon these annual occasions, to a gentleman of European reputation—a Fellow of the two leading scientific societies in the British Empire, whose extensive acquaintance with all branches of research specially fitted him for the position of the leader and President of the Royal Society of Victoria. Under him the Society has grown up; to him the scientific workers of this colony look as to a father in science, ready at all times with advice, information, and assistance. Under his wise rule our affairs have progressed smoothly and successfully, good work has been done, and we have shown to those residing in other parts of the world that, amidst the turmoil and excitement, the rapid changes and animated contests that characterise the founding of a new empire in a land but a few years since unknown and unoccupied, the arduous paths of scientific investigation are not wholly deserted, nor the labours of the great masters of research altogether unappreciated. But now the familiar face is no longer seen, the familiar voice no longer heard from the presidential chair. While yet in the full vigour of his strength and usefulness, he has chosen to withdraw from the position of greatest prominence, and to serve the Society in a sphere similar to that occupied by Nestor amongst the Grecian leaders before Troy. Long may he continue to aid by his wise counsel and effective support the future Presidents of the Royal Society of Victoria.

It was with some trepidation that I understood that there was a probability of my being proposed as a candidate for the vacant office. To give satisfaction in a position long occupied by such a veteran in science as our late President must assuredly be by no means easy, while any shortcoming cannot fail to provoke unpleasant comparisons. But while the words *nolo episcopari* well expressed my private sentiments, I felt that I should be acting an unworthy part were I to decline the combined honour and responsibility my brother scientists were anxious to confer upon me. Thus, though strongly of opinion that it would have been better had the choice fallen upon some older and more experienced member, I accepted the office, and crave your kindly indulgence for my inaugural address.

And now, and appropriately, at a meeting at which many visitors or non-members are present, let us inquire, What is a Royal Society, and what are its objects? *The* Royal Society, it may be replied, is that great and honoured association of learned men which had its origin, under kingly patronage, in London more than two centuries ago, and which from that day to the present has interested itself in all branches of science, and has included in its membership the most illustrious names the world has known. It assisted in publishing Newton's Principia; it aided Bradley in his great discoveries of aberration and nutation; it introduced the Gregorian Calendar; it encouraged Harvey in his discovery of the circulation of the blood; to it Dollond and Ramsden, Davy and Cavendish, Faraday, Herschel, and a host of other scientific worthies are indebted in a thousand ways. Its published Transactions are most voluminous, and are to be found in every library of scientific pretensions. Through evil report and good report; hissed at by the vulgar, who, in their ignorance, thought they had been robbed of eleven days out of their lifetime; ridiculed by wits and satirists, who were unable to grasp the importance of real knowledge, and to whom exhaustive experimental investigation looked like childish trifling—the Royal Society held on its way; and now in its maturity, and with all its glorious history behind it, stands one of the grandest and most beneficent organisations the world has ever seen.

The Royal Society recognises no authority but that which submits to the most crucial test. It does not accept the law of gravitation because Newton enunciated it, or the circulation of the blood because Harvey described its course, but it places Newton and Harvey in the highest seat of honour, because the facts they first pointed out have been verified by every succeeding investigation. Its methods are accurate observation, conscientious experimenting, logical deduction. Its aim is not the advocacy of a theory, the bolstering up of a case, but the discovery of absolute truth.

In humble imitation of this magnificent association, local societies such as our own have been formed in many countries, and have enjoyed in various degrees the public favour and the support of Government. These are known as the Royal Societies of Victoria, New South Wales, South Australia, or otherwise, as the case may be. They recognise the same duty, adopt the same methods, and keep in view the same objects as the parent Society. To discover and record that which is true, to widen the bounds of human knowledge, to expose error, to assist the *bonâ fide* investigator, this constitutes their legitimate work.

But why, some one not specially interested in scientific pursuits may ask, all this enthusiasm about truth? Do we not all seek truth? and is not truth easily attainable in most matters of practical moment? We are intelligent men; we do not believe in witchcraft and astrology; we belong to the enlightened city of Melbourne in the last quarter of the nineteenth century. Ah! my friends, if you read history, you will find that those of olden time who burnt witches and consulted the stars, who persecuted Galileo and denounced the system of Copernicus as impious, were experienced, sensible, enlightened people—at least, in their own estimation; and it will be no astonishing thing if not a few of the beliefs and practices of the present day come in a century's time, to be regarded as we now regard astrology and demonology.

The human mind is peculiarly susceptible to bias. It is like a compass, which, left alone, points to the pole, but is most easily deflected by any magnetic mass in the vicinity. Nothing is easier than to take a side and fight for it through thick and thin; nothing more difficult than to preserve an unbiassed mind, to suspend judgment until the evidence is all duly set forth. We are born advocates, but we need long and severe training before we become competent judges. To hold the balance true is, then, the part of the really scientific mind—a part most difficult when gusts of personal feeling or the attractions of personal interest affect one all the time. Even in the history of scientific discovery it is most noticeable how an ingenious man concocts a clever theory, and then becomes enamoured with his own creation, and resolutely refuses duly to weigh the evidence against it; while as to inventors of schemes of supposed practical utility, I speak from a large experience when I say that they are, as a rule, utterly unable to form any sound judgment whatever upon their own proposals.

Rest assured, then, that the amount of fallacy, error, and prejudice existing amongst us is far greater, and the amount of real knowledge far less, than we fondly suppose; and the noblest use of life is to expose error and bring truth to light, even if the error is of the most apparently innocuous sort, and the truth of the least obvious importance.

But what of the practical value of scientific knowledge? Do not scientific men, some one will probably ask, spend years of valuable time in learned trifling, in elaborately investigating matters of little or no real importance? The reply is, that the true philosopher seeks knowledge for its own sake, and in finding it experiences the highest intellectual joy. To him life is more than meat, and the body than raiment; and to explore the dim beginnings of organised creatures in remote geological epochs, to observe the genesis of a new world in some inconceivably distant region of space, or to measure the size and investigate the properties of the ultimate atoms of which the universe is built up, affords a profound, a noble satisfaction, so that he is infinitely happier amongst his formulæ and specimens, his fossils and re-agents, than, in their absence, the wealth of Crœsus could make him.

But, further, it is to be observed that it not infrequently happens that lines of investigation of the most apparently useless kind ultimately lead to results of the highest practical importance, which would have been altogether missed had the investigator too anxiously asked, *Cui bono?* at the outset. Had the scientists of the centuries preceding our own not faithfully and patiently laid the foundations of mathematical and physical science, we should never have had the wonderful practical developments which at the present time are amongst the first necessities of life and the most potent appliances of civilisation. They laboured, and we have entered into their labours. Had they not spent precious years upon apparently trivial inquiries as to why pumps would not suck from a greater depth than thirty-three feet, or what was the reason that the legs of a dead frog twitched when touched with a piece of metal, we might not have had our ocean steamships, our swift locomotives, or our wondrous telegraphic system, permeating the whole civilised world as the nerves do the sentient human body. All honour to the worthies of old who, without the faintest presentiment of the wonderful result, patiently and conscientiously did their duty, and laid the foundations of the glorious temple of science in which we, their happy successors, worship.

There are lines of scientific investigation in various directions which are at present in a similar state to the science of physics in the days of Galileo or Galvani. To the keen practical business man, who looks for immediate results expressible in terms of pounds, shillings, and pence, they are apt to bear the aspect of laborious trifling. A century hence, when we have passed off the scene, we know not but what they may lead to results of incalculable value, and the names of those who at present labour in obscurity be extolled as the greatest benefactors the human race has ever known.

Then, again, it is to be remembered that the various sciences are mutually dependent—the well-being and advancement of each requires that the other should not be neglected. The astronomer is constantly indebted to the mathematician, the chemist to the electrician, and *vice versa.* Not only the results, but the words of inquiry adopted in one direction throw new light upon apparently remote questions. Hence the importance of all-round education, and the danger of too close specialisation. Hence the desirability of bringing scientists of various orders into contact, and the advantage of having one general Society, such as our own, with its necessary sections devoted to special studies, rather than separate and independent societies, conducting their affairs without reference to each other, and affording no opportunity for that intellectual friction which ensues when men who have been educated in different ways, and whose pursuits tend to develop different mental qualities, come together.

POSITION AND PROSPECTS OF THE SOCIETY.

The Royal Society of Victoria, now twenty-seven years old, is in a fairly prosperous condition financially and otherwise, though the meetings are not so numerously attended as we might desire. The discussions depend too much upon a few regular speakers, and thus lack the interest that springs from variety. No doubt the numerous societies for special purposes compete with the present body, and divert in another direction much of our younger talent. Could our friends have seen their way to come in and form sections of the Royal Society, I cannot help thinking it would have been advantageous to all parties. They would have imparted life and vigour, while we lent dignity and prestige, and secured a more permanent record and wider circulation for their investigations. However, it has been decided otherwise, and we ought to rejoice at the numerous manifestations of scientific activity, even though they do not take place under the immediate control of the Royal Society. Our library continues to grow by constant accessions, and our Transactions are eagerly sought for by similar institutions in other lands, who send us their publications in return. The question of increased accommodation is at present in the hands of a committee of the Council, and should they report favourably it is gratifying to know that land on which to build, and funds to meet the expenditure, will not be lacking.

A number of interesting and valuable papers have been read during the year. Of the questions discussed, that of a glacial period in Australia is perhaps the most interesting. The discussion was opened early last year by an exhaustive paper by Mr. Griffiths, who maintained that the beds of boulders found in many parts of our colony, notably on our goldfields, cannot be accounted for by the comparatively feeble action of streams with restricted watersheds, but need a more potent agency, that of ice, to fully explain them. The explorations of Dr. Von Lindenfeld, at Mount Kosciusko, appear to have led to the identification of the well-known glacial phenomenon of rocks planed down to smooth and flowing outlines. More recently Mr. Stirling, who has done so much to elucidate the flora and meteorology of the Australian Alps, has submitted specimens of supposed glaciation from the neighbourhood of Omeo. With regard to these specimens there has been some difference of opinion; but even those who question the evidences admit the reasonableness of the theory.

Of the sections—the formation of which the laws of the Society provide for—Section A is the only one *in esse*, the others being merely *in posse.* Section A meets regularly, and does good work in discussing engineering questions or the day, amongst which the Cootamundra disaster, the discharge of streams, the design of beams and girders, the production and distribution of electric currents may be noted.

DECEASED MEMBERS.

The Society has lost several members by death during the past year.

Mr. Gillbee, M.R.C.S., was one of the founders of the Royal Society of Victoria, and at one time held the position of Vice-President. He took an active part in connection with the Burke and Wills expedition, and at the time of his death occupied the position of President of the Medical Board of Victoria.

Mr. E. Davy, M.R.C.S., was one of the early investigators in telegraphy, and to him is due the invention of the relay. His meritorious services were long overlooked, but recently his claims have been recognised. Shortly before his death he contributed a paper on the "Extinction of Waves" to the Transactions of the Society.

Dr. Edward Barker was one of the earliest members of the Philosophical Institute, which afterwards merged in the Royal Society, his name appearing on the roll in company with those of Sir H. Barkly, Sir W. A'Beckett, Sir Redmond Barry, and other founders of the Institute.

Dr. David E. Wilkie was also one of the earliest members, and at one time a contributor to the Transactions. He occupied the position of Chairman of the Exploration Committee of the Philosophical Institute.

KINDRED INSTITUTIONS.

The Field Naturalists' Club reports steady progress. With a membership of one hundred and sixty, with well attended meetings, interesting papers, and pleasant excursions into the country, it seems to be in the heyday of its youth and vigour. Unlike other scientific bodies whose votaries all belong to the sterner sex, the Field Naturalists' Club presents singular attractions to our lady friends, of whom about twenty are members, and some of them office-bearers. The Club has laid the public under an obligation by its endeavours to prevent the destruction of spots of natural beauty near Melbourne.

The Geographical Society of Australasia is engaged busily in practical work. A number of valuable papers have been read and published, and, in addition to this, an exploring party has been sent to New Guinea, the expense of which is defrayed from sums contributed by the Governments of Queensland, New South Wales, and Victoria. The Society has branches in New South Wales and Victoria, South Australia, Queensland, and Tasmania.

A Historical Society has recently been constituted, and has held a very successful inaugural meeting. It proposes to rescue from oblivion, while yet it is possible to do so, accurate particulars concerning the exploration, settlement, and early history of the Australian colonies. How desirable such a work is, is evidenced by the contradictions, confusion, and uncertainty which already invest the early chronicles of our land.

The Pharmacy Board and Pharmaceutical Society have continued their work during the year, the subjects dealt with being chemistry, materia medica, and botany. A special arrangement has been made for a lectureship in pharmacy for the medical students of the University. The museum of specimens and the library have received valuable additions, and the work of instruction has been greatly facilitated by the ample accommodation provided by Government.

The Microscopical Society does not relax its endeavours, and the gentlemen belonging to it year by year lay the Royal Society under great obligation by the interesting and attractive exhibits which form so prominent a feature at our annual conversazione.

The Industrial Museum and School of Technology, under the direction of Mr. J. Cosmo Newbery, efficiently perform their functions. The collections of minerals are constantly being made more complete, and the classes in Chemistry, Mechanical Engineering, and Telegraphy continue to attract students, the Telegraphy Class being particularly popular.

The Museum of Natural History, under the able directorship of Professor M'Coy, is from time to time receiving valuable additions, and the need for extended accommodation is daily becoming more apparent. There is room upon the site at the University for a second building of similar dimensions to the existing one, and it is to be hoped that this may before long be provided. The position of this Museum in the University Grounds adds greatly to its educational value, as the University students are enabled at once to inspect the specimens, and verify with their own eyes the statements they have listened to in the lectures.

The Schools of Mines at Ballarat and Sandhurst continue to flourish. At Ballarat a new chemical laboratory has been fitted up, and the museum and library are becoming more complete every year. A set of standard thermometers and a standard barometer are daily observed, and a proposal for the affiliation of the institution to the Melbourne University is under consideration. At Sandhurst similar work is being done. A museum, a well-equipped meteorological observatory, field lectures on geology, and popular science lectures are established, while a mechanical workshop and astronomical observatory are in contemplation. It is to be hoped that in course of time every large centre of population in Australia will be provided with a similar institution for the purpose of imparting reliable information on scientific subjects of practical importance.

THE MELBOURNE UNIVERSITY.

This, the great centre of higher education for the colony, attracts a larger number of students every year, there being at present between four and five hundred in attendance upon lectures. In every branch we find increasing activity, and the very defects and evils which we cannot avoid seeing are due to the unexampled rapidity with which the institution has grown. Not only is the accommodation insufficient, but the arrangements and organisation, which worked well with a quarter the number of students, and less than half as many courses of lectures, are now overweighted. The want of accommodation, as far as the Medical School is concerned, has been met by the erection of a handsome stone building, fitted with every modern improvement; but the Arts and Engineering Classes urgently need costly extensions. Larger lecture theatres, modern apparatus, a physical laboratory, a powerful testing-machine for investigations upon the effects of stress on materials, have been asked for, and it is to be hoped will before long be obtained. These, together with additional teaching power, will go far to enable our University to take a proper stand, and not fear comparison with Universities in older countries.

ASTRONOMICAL WORK.

The results of the work done with the great Melbourne telescope are now being published, and comprise descriptions and lithographs of the southern nebulæ as observed by Mr. Le Sueur, Mr. M'George, the late Mr. Turner, and the present observer, Mr. Baracchi.

The new transit circle referred to by our late President last year gives every satisfaction after a year's trial, and is without doubt unsurpassed by any similar instrument elsewhere.

In September last a total eclipse of the sun took place, visible in New Zealand. It was at first proposed to send a party of observers from Melbourne, but the idea was abandoned in view of the uncertainty of the weather at that time of the year. The eclipse was observed by the local astronomers with but partial success, owing to cloudy weather and snowstorms. In Wellington the best results were obtained, the character and position of the corona being well seen, and some good photographs obtained.

Several small telescopic comets have been observed during the year.

An interesting theory is propounded by M. Faye in the *Comptes Rendus*. He explains the comparatively uniform temperature of the globe without climates or seasons in early geologic times, by supposing that the earth was then warm with its own heat, while the sun was a vast and barely luminous group of meteors.

The past year has not been a very eventful one in astronomical circles. Steady work and gradually increasing efficiency have characterised it, rather than novel and startling discoveries.

ENGINEERING.

No very remarkable engineering work has been initiated or completed during the past year. The Great Forth Bridge in Scotland slowly progresses, but years must elapse before it is completed. With its huge girders, spanning 1600 feet without a support, it will be at once the most gigantic as well as the most original structure in the world.

A structure of a type not uncommon in America, but new in Australia, has been erected by the Victorian Railway Department over the River Werribee, and will shortly be ready for traffic. It is about a quarter of a mile long, and 125 feet high from the water level.

The Panama Canal progresses slowly. It is an enormously more difficult work than that at Suez, owing to hilly ground, flooded rivers, and the unhealthy climate. It will be many years before we can hope to send our mails and passengers through it on their way to Europe.

In December, 1883, I submitted a brief paper to the Society, in which I pointed out that, in view of the ascertained laws of Thermodynamics, the possibilities of improvement in our best steam engines were very limited, whereas in the case of the gas engine they were enormously wider, and that therefore the gas engine, which even then was superseding steam under certain special conditions, might be expected to come into much greater prominence, and be used on a very large scale. This prediction is, according to accounts received from England, in a fair way to be accomplished. Not only have gas engines of the ordinary type—a type that is, theoretically, very imperfect—succeeded when supplied with gas from a suitable gas-producing apparatus in giving as much power per pound of coal as the very largest and best steam engines, but a new type of gas engine has been brought out, in which the principal defects of the present form are remedied, and which, provided no unforeseen practical difficulty intervenes, will nearly double the power obtained from a given quantity of gas. This new engine, in conjunction with a proper gas-producer, should far excel in economic result any steam engine ever made or likely to be made. Amongst other advantages that will accrue from the extended employment of gas as a motive power will be the cessation of boiler explosions and the abolition of the smoke nuisance, both matters of the highest importance in large cities.

In electric lighting a substantial advance is being effected. The age of extravagant expectations and reckless speculation being over, steady, slow, but healthy progress is the order of the day. The incandescent lamp is now regarded as a necessary fitting on board passenger steamers of any pretensions whatever, while on land permanent installations for public buildings and private mansions are being from time to time made. A great *desideratum* is some means of storing up the electricity, some arrangement which shall play a part analogous to the gasholder at a gasworks. At present we work on what may be called the hand-to-mouth system. The electricity is used just as fast as produced. The slightest variation or most transient stoppage of the generating mechanism dims or extinguishes the light. Could we obtain some reliable accumulator or storage battery it would afford invaluable help. But though many such batteries have been made and tested, none have proved permanently reliable. We must therefore do the best we can without them, and by means of better engines, more accurate governors, efficient dynamos, and other improvements, coupled with increasing experience on the part of those who manage the system, breakdowns can be rendered very infrequent, even if they cannot be wholly abolished.

The transmission of power by means of electricity does not progress much, though an interesting example has recently come into existence in New Zealand, and a few electric tramways are running in Europe. There is not much difficulty in effecting the result, the operation being by no means so delicate as the production of electric light, but other and rougher means suffice to attain the same object. We are about to have tramcars propelled through our city by means of underground cables of enormous length. Suppose, instead of these cables, we placed metallic conductors in the tunnels that run along our streets, and thus conveyed the power from dynamos at the engine-house to electro-motors upon the cars, we could unquestionably carry on the traffic; but whether the cost of coal for the engines, the cost of maintaining the apparatus, and the risk of derangement, would be as small under the electrical as under the mechanical system can only be ascertained by experiment. As a mode of transmitting power, electricity has several formidable competitors. As an illuminant it really should have none, for it is the only illuminant that is unobjectionable from a sanitary point of view.

The most notable advance in telegraphic matters in our own corner of the world is the duplication of the Tasmanian line. The cable steamer "Sherard Osborn" charged with this work is at present in our waters, and will shortly lay a second wire across the straits. This will ensure constant communication, in spite of occasional temporary interruptions of either line.

The much-desired abolition of overhead telegraph and telephone wires in our cities is not yet *un fait accompli.* Every year the poles grow larger, and the web of wires thicker, till they threaten like the Parthian arrows to darken the sun. Not only do these masts and wires seriously mar the architectural effect of our most costly buildings, but they constitute a very perceptible source of danger by breaking or sagging so low as to come in contact with passing vehicles. He who succeeds in indicating a successful mode of disposing of the maze of electric conductors underground or out of sight will indeed be a public benefactor.

The great question of water conservation still engages earnest attention—Royal Commissions have been taking evidence both in Victoria and New South Wales, while a Victorian minister, accompanied by his professional adviser, has visited America, and inspected the water-supply works there. Various schemes are proposed or in progress under the various water trusts in this colony, and some curious questions of intercolonial water-right are looming. It is to be hoped that our engineers will hasten slowly, and that the inception of a general irrigation system will not be characterised by the mistakes, disasters, and waste of money that have accompanied some of our domestic and mining schemes of water supply in days past.

There is one work of which we may speak with unhesitating commendation, and that is the systematic gauging of our principal streams. This costs but little, and if regularly carried out will in a few years supply us with data of the highest value to the engineer, whether he be constructing reservoirs or bridges, railways or schemes of water supply.

AUSTRALIAN BOTANY.

The valuable work undertaken by our State Botanist and fellow-member, Baron von Mueller, continues to advance. An enlarged edition of *Select Plants for Industrial Culture and Naturalisation* will be in the Government Printer's hands by the end of the year. An atlas of 80 quarto plates of the *Myoporinæ* will be exhibited at the forthcoming Indian and Colonial Exhibition. The *Census of Australian Plants* will receive a new supplement at the end of the present year. The *Dichotomous Key* for the naming of

Victorian plants is making progress, but is found to be a more laborious task than was at first anticipated. The sixth part of *Descriptive Notes on Papuan Plants* has been published, and great results are expected from the botanical work of the two expeditions at present engaged in exploring New Guinea.

New species of Utricularia have been discovered in North West Australia, and additions to the flora of Queensland and New Caledonia have been duly recorded.

Our Botanical Gardens, under the supervision of Mr. W. R. Guilfoyle, are in a flourishing state; the moist weather and warmth have given rise to an unusual display of both foliage and flowers. The limited extent of the conservatory accommodation, hampers the cultivation of the many valuable exotics. This circumstance is to be regretted, and it is to be hoped that the comparatively small sum necessary for extension may be speedily obtained. The classification and nomenclature of plants is not neglected, and facilities are afforded for students of botany, pharmacy, &c., to inspect and form collections of their own.

In concluding this address, permit me to urge upon our members, and especially the younger ones, the importance of regular attendance upon the meetings, and the duty of taking part in the discussions, and contributing papers on subjects of scientific interest. The field of research is unlimited. Many important lines of investigation are as yet almost untouched. There is work for all—work that will extend the knowledge and promote the happiness of the human race. As the older members are removed by death, or laid aside by the infirmities of age, we ought to have young scientists full of enthusiasm ready to take their places, to bear the burden, and reap the reward. What can be more replete with the highest enjoyment, upon what can we look back with greater satisfaction, than a life spent in the search after truth, in combating error, and aiding the material and intellectual well-being of our fellow-men?

TRANSACTIONS.

Art. I.—*The Examination of Waters.*

By J. Cosmo Newbery, B.Sc., C.M.G.

[Read 16th April, 1885.]

This subject, being one of the very greatest importance to the well-being of any community, has at the present day a literature of its own in almost every modern language, and numbers of able men—engineers, medical men, microscopists, and chemists—are devoting themselves to the study. The results of their labours show the necessity of having pure drinking water, and the absolute elimination of all possible sources of contamination by sewage matter.

For a number of years past I have been examining, in a more or less irregular manner, the waters of Victoria—in former years, with the assistance of the late Mr. Manley Hopwood and my late assistant, Mr. Frederic Dunn, now our public analyst, and more recently with Mr. Savage and Mr. Dunn. Some of our analytical results have appeared in the publications of the Department of Mines; and I must admit that if these are taken into consideration without full knowledge of all the circumstances connected with the method of collection and the sources of supply, they form a most confusing table, and without such information give but little idea of the real condition of the water from a sanitary point of view, especially when taken singly. For instance, an undoubtedly contaminated well-water from Kyneton gave us in parts per million: Free ammonia, 0·19; albuminoid ammonia, 0·22; while rain-water from the Observatory gauge gave: free ammonia, 1·088; albuminoid ammonia, 0·947. The rain-water was the first which fell after a long drought, and had washed a contaminated atmosphere.

A chemist may, by any of the well-known methods, determine the amount of nitrogenous matter contained in the water, as free or saline ammonia, albuminoid ammonia, nitrites or nitrates, and from the results obtained, with or without an estimation of the amount of combined carbon and chlorides present, form some idea of its character; but these determinations do not prove in the slightest degree whether the water is fit to drink, or whether it carries the germs of disease, ready and able to reproduce the disease whenever any one of the germs may meet a suitable subject.

When the results obtained are what may be considered abnormal, they simply show that a source of contamination should be sought for; and for this reason these tests should be continually applied to all our large sources of public supply. The determination of combined carbon and chlorides seems to me to be of less value here than in England, for all our surface waters are more or less saline, with the exception of those derived from the mountain ranges and the more elevated portions of the colony. Many of the streams in the more level parts of the colony become brackish during droughts, or in our ordinary summer weather; and an idea of the amount of salt these streams carry may be formed when we look at the lakes in the Western District, and see that all those which have not some natural outlet become strong brines during the summer months, though they are filled by streams of almost tasteless water in the winter; they yield annually many tons of salt to the factories. In most of our river valleys we have numerous mineral springs, many of them yielding waters charged with alkaline carbonates; and these alkaline salts, acting upon the dead organic matters, dissolve some of the carbonaceous substances, and carry it into the stream and reservoirs. These facts show that we must be very careful in drawing conclusions from our analytical results. If we have some previous knowledge of the impurities in a water, our analysis will, however, indicate any changes that may be taking place, and the necessity for a careful examination of the sources of supply. For instance, in the year 1877 the waters from the Geelong supply gave as an average in one million parts, 0·00085 of a part of free or saline ammonia, and 0·0076 of albuminoid ammonia, and still less nitrogen as nitrites or nitrates. The water which had been cleared by lime contained only a little more than one-half of the quantity of albuminoid ammonia given in these small fractions, and the people of Geelong flattered themselves that they had one of the purest water supplies in the colony.

At the present time we find 150 times as much free ammonia, and of albuminoid ammonia nearly 200 times as much, besides a very notable amount of nitrites and nitrates

—over three per million. A similar statement may, I am afraid, be made with regard to almost every public water supply in the colony, except Yan Yean, which, owing to the great care taken, is steadily improving, and, apart from its colour, is an exceptionally pure water.

The figures just given do not prove that the water is poisonous; and we know that the people of Geelong who drink this water have not suffered more, or as much, from typhoid fever—the real filth disease—as the people who are drinking the purer Yan Yean; and this argument, amongst others, is used to prove that though the water has chemically deteriorated to such a great extent, it is still a wholesome water. To investigate it further, I tried to follow the experiments described by the late Dr. Angus Smith in his last report to the Local Government Board of Great Britain, dated 1884, and convinced myself that the water was directly contaminated by filth. I found many difficulties in following Dr. Smith's experiments; but even though not successful in proving the quantity or energy of the contamination, I found no difficulty in developing a large variety of bacteria only to be found in filthy water, or water contaminated by filth. I find similar bacteria in the waters from both branches of the Moorabool, Lal Lal Creek, Stoney Creek reservoir, some cattle tanks near the Anakies, the Clunes supply, the Coliban, the Wimmera at Dimboola, the Horsham supply, and several others.

I feel considerable diffidence in naming the various forms which I have observed, as some do not agree with the descriptions given by the "best authorities," and of late we have seen that these same "best authorities" do not agree with one another, not only about the name a certain form shall take, but also as to whether these interesting micro-organisms are vegetables or animals. I have no doubt, however, that I have recognised in the waters named all the common types of bacteria which always accompany filth. The greatest variety of forms are to be found in the water from the Western Moorabool and Lal Lal Creek, and they may be developed by any of the ordinary means in such numbers in a bottle of either of these waters that in a short time it is simply a bacteria jelly with an offensive, sickly smell. The number developed may in some measure have prevented my being successful with Dr. Smith's gelatine method, as these organisms render a thin gelatine jelly liquid, and if the jelly is too stiff they do not seem to have the power to act. At the time I was making my experiments the temperature of the laboratory often rose to 80° F., and, as at this temperature the 5 per. cent. jellies became liquid, the bacteria were able to move freely through the tubes, the experiments were lost.

I then used the well-known solutions of tartarate of ammonia, phosphate of sodium, sugar, and nitrates, singly and mixed, having previously carefully sterilised them by boiling, and using precautions to prevent outside contamination, and as a check testing distilled water contaminated by the air of the laboratory. In these experiments the Yan Yean (filtered) was the only natural water which would not develop its germs without the addition of ammonium tartarate. When mixed with sugar the mud separated from the Yan Yean water by a high-pressure filter produced alcohol—(another exception, which can hardly be called a natural water, is the water from the Lovely Banks Reservoir, which has been treated by lime)—while all the other waters became offensive, producing ropy liquids undergoing putrefactive changes, giving off hydrogen, and smelling at times of butyric and lactic acids.

Most of my experiments were repeated several times, and I noted that in those waters which contain the germs of many varieties of bacteria the sequence of development and duration of the existence of each class or variety might be varied by slight alterations in the method of treatment; and this may in some measure account for the contradictory statements made by scientific observers as to the types found in certain waters, and the chemical changes produced by them. With this part of the subject I hope to be able to deal at a future time, but in this inquiry I was satisfied in obtaining evidence which confirmed the results of the chemical tests, proving the contamination by filth, and that the germs introduced by this filth contamination were still active. While these experiments were being conducted I had the opportunity of visiting one of the watersheds in question —the Moorabool—under the guidance of Mr. Wm. Davidson, the engineer of the Yan Yean Water Supply, and found that the river, with its tributaries, is simply the drain of a pastoral and farming district, with a rapidly increasing farming population.

Some pure water may get into the river from springs along the banks, and before the recent rain these springs may have contributed a considerable proportion of the very limited stream, and at the same time account for the large amount of saline matter present, amounting to from 16 to 20 grains per gallon. But after the rain the main supply will come from the small tributary streams and soakage, the best of which will take their supply from well-stocked pastures and farm lands, and the worst from farmyards, piggeries, dwellings, and closets. A glance at a recent map of the colony will show that a similar state of affairs must exist, more or less, in the collecting area of most of our water-supply schemes, Yan Yean excepted. I am told that the Yan Yean catchment area does not receive the drainage of a single dwelling of any kind, and this statement proves the accuracy of the methods of detecting filth. We found none. The future management of the other schemes will, I fear, tax the energies of our engineers if they are called on to give pure water, for as population increases these waters must become worse. I don't wish to meddle with the medical aspect of the case beyond my own sphere; but we all acknowledge that typhoid fever is only communicated by means of excreta, that it is essentially a filth disease, that it is now very prevalent throughout the colony, and that water is the best possible carrier of the disease. What I have shown proves—first, chemically these waters should be suspected; second, microscopically they contain living forms, only found in connection with filth; and third, in the case of the Moorabool, ocular demonstration may be obtained of direct pollution; and I have no doubt I should have found the same evidence of pollution on visiting the other watersheds in the populated districts. It may be asked why, with such a foul watershed for its supply, Geelong has not suffered more from typhoid fever; and there are, I believe, known cases within the water supply area. The answer, I think, is, that the source of supply has been dry while typhoid has been prevalent, and that there is no intake to the reservoirs, and that the method of treatment of the water by lime at the Lovely Banks Reservoir to a very great degree destroys the living germs. To what extent this lime treatment may be effective in killing fever germs is unknown. It prevents the development of Stoney Creek Reservoir bacteria; but in the Lovely Banks water I find certain minute living cells, and the presence of life of any kind throws a doubt upon the value of the process. Somewhat similar means are adopted to purify the water drawn from the Thames for the supply of London. Above the point at which the water is taken there is a very large population; but the circumstances are not similar to ours; and compared to the Moorabool or smaller streams which supply the reservoirs in question, the Thames is a great river, and chemical changes caused by the very filth that falls into it may tend to purify it; and, further, we can have no evidence whatever of the amount of disease that it actually conveys. I may quote from an essay on water supply, by J. H. Balfour Brown, lent to me by Mr. Davidson. He says, in writing of purified sewage:—"Common sense is revolted by water which is mixed with sewage, and although common sense is often behind science, in many cases, like children who stray before grown-up people, it runs before. The chemist cannot point to the specific infecting substance, but can tell you whether the water is open to suspicion; whether it is injurious to health can only be determined by physiological tests. Dr. Frankland, than whom we have no greater authority, says normal sewage may be drunk with impunity; water mixed with healthy sewage is quite wholesome to drink; probably half the population of the country (England) are drinking such water." But what happens if the sewage is not healthy? I need not quote the well-authenticated instances in which one single individual has contaminated a water supply, and by this means has communicated the disease to hundreds; of how in the village of Lausen the poisoned water had to filter through a mountain range before it reached the victims, and yet the filtering power of the mountain rocks through which the water passed was sufficient to prevent the passage of starch granules, showing that there was no fissure or channel through which to convey solid particles. Nearer home we have an instance that would be worth investigating. The New South Wales Government made soakage dams below the new town of Silverton, in a direct line with the natural drainage, and during the late drought all water had to be obtained from these dams or wells in the sand. Typhoid was taken to the new town, and in a very short time the local hospital was too small to hold the number of typhoid patients. Recently we have had numerous filters devised which pretend to prevent the passage of germs, but at present I have not met with one or been able to make one which answers the purpose. The high-pressure filters now coming into common use, in which there is a cell of earthenware, will separate the minute bacteria forms from the Yan Yean, but the beautiful, bright filtered water obtained from this filter contains their germs. Some good scientific observers claim to have made filters which will separate germs; but it is possible, I think, that they have been experimenting on water in which the bacteria were exhausted or dying, and in which there were no germs; for after they (the bacteria) have brought about the chemical changes of which they are capable they do die out; and it has been a point of interest to watch how each of the waters under examination passed through its various stages, and one form replaced another till all died. Whether we ever reach a stage in which there are no germs present I am not certain, but think that it is probable, and that in the rapid changes the disease germs may suffer in the same way as harmless bacteria. Bacteria are so easily killed, and it is so easy to destroy, or perhaps I should say prevent, their germs from developing that we may hope for some means for in a like manner destroying disease germs, and I think some simple salt may do this.

But, as Mr. Balfour Brown says, for proof in connection with this subject "we must be content to wait for the fuller revelation, which may be reached through long bills of mortality in time to come;" and quoting from Dr. Cayley's Croonian lectures, "I think these two instances (the Catherum and Lausen cases) are sufficient of themselves to serve as a warning against trusting to irrigation and downward filtration as a means of purifying water, and also against the dictum that water containing less than a certain proportion of organic impurity is practically wholesome and fit for drinking irrespective of its original source. It ought, I think, to be laid down as a rule of hygiene that human excrements should under no circumstances be mixed with drinking water, however completely they may be subsequently removed by filtration or rendered innocuous by oxidation. Of course, in the case of London this can only be looked upon as an ideal to be realised in some distant future; but with less than this we ought not to rest satisfied." "Living matter," says Dr. Alfred Hill, "does not get oxidised by flowing down a stream any more than a fish. It is not decomposing animal matter which is prejudicial, but actual living matter. Mere dilution by water does not deprive it of its dangerous qualities." Dr. Frankland says: "I do not think it possible by any practical means that have been suggested so to purify water as to guarantee its freedom from these germs of disease." And these authorities believe that "if a spoonful of unhealthy sewage is put into the Thames at Oxford it may poison some persons in London."

In a recent article in the *Argus* I noticed a statement that during the epidemic of cholera in Italy none of the people employed in the manufacture of borax, or in connection with the works, were attacked by the disease. The claims of borax as a disinfectant and preservative for food have been advanced a great many times of late years, but without much success. But seeing the statement referred to, I added a boiled solution of borax to some freshly filtered water, together with sterilised ammonium tartarate and sodium phosphate, and though the bottle has stood in the laboratory for 30 days there are no bacteria yet to be found in it. The same water, treated in the same way, but without borax, becomes cloudy with bacteria in two or three days; and in the same water unfiltered, in which there are developed bacteria, the borax has no effect; the increase in number goes on just as rapidly with as without it. This explains some of the contradictory results obtained with borax and boracic acid. It has some effect on the germs, but not on the developed bacteria. If the statement from Italy is true, and I see no reason to doubt it, the explanation seems to be that all the water about the borax works contains this salt, and the workmen are continually taking it into their systems, and that the germs became passive, or died in the borax water. On fully active bacteria I have tried the action of several so-called disinfectants, and find that dilute solutions have little or no effect. They swim about in a distinctly purple solution of permanganate of potash, and seem to reject it; and 1 per cent. carbolic acid takes a long time to kill them. Lime water kills them, but not if too dilute; but lime-like borax seems to prevent the growth of the germs, and a mere trace of benzine destroys both germ and bacteria, and probably most hydro-carbons do the same; and we may yet have to return to the work of the late Dr. Day, of Geelong, and study the action of hydro-carbons, and the formation of peroxide of hydrogen, and there find our best disinfectant. These crude experiments, with which I do not offer any figures, as I do not yet know the minimum quantity of disinfectant required, suggest many others. Though it is possible that some means may be found to prevent infection by killing germs in poisonous waters, I hardly think that any portion of our community will be satisfied to accept as a water supply one which may largely consist of sterilised sewage.

TABLE SHOWING NITROGENOUS MATTER IN SOME OF THE WATERS REFERRED TO.

(Amounts given in parts per million.)

Locality.	Free Ammonia.	Albuminoid Ammonia.	Nitrates and Nitrites.	
OBSERVATORY GAUGE—				
January	0·1088	0·0947	0·1334	
Mar. 14th & 15th	0 5598	0 0799	0·2499	
,, 15th	0·3998	0 0622	0·1419	
,, 31st	0·0999	0 0499	0·1500	
April 17th	0·2503	0·1001	0·2002	
,, 21st	0 2002	0·0500	0·3002	
,, 26th	0·1000	0·0500	0·4005	
May 10th to 15th	0·2603	0·1001	0·4505	
,, 30th to 31st	0 3103	0·1939	0 2326	
June 7th to 13th	0·0640	0·0512	not determined	
,, 13th to 14th	0·2560	0·1152	,,	
,, 17th to 20th	0·3712	0·1920	,,	
Museum Yard, Jan.	0·0788	0·0710	0 12	
,, ,,	0·1261	0 0788	0·123	
Observatory gauge, Thunderstorm Jan.	2·3790	0·6608	0·395	after long drought, 21st January, 1879
MT. MACEDON GAUGE—				
April	0·5914	nil	0·045	
May 26th to 30th	nil	,,	nil	
Sept. 22nd to 27th	0·3984	0·1092	0 3664	
Oct. 7th to 18th	nil	nil	nil	
,, 18th to 19th	0·225	,,	0·1992	
Nov. 24th to 26th	0·623	0·0900	0·3985	
Dec. 18th & 19th	0·4564	0·1092	0·2185	
,, 19th	0·2828	0·1671	0·3985	
Yan Yean Reservoir	0·1001	0·2003	0 3004	9th February, 1880
Middle ,, ,,	0·0200	0·4500	undet.	3rd May, 1880
Plenty River	nil	0·1001	,,	23rd February, 1881
Yan Yean Intake	0·0350	0·1001	,,	22nd January, 1881
West Moorabool	0 0265	0 106	0 119	March, 1885
Fiskin's Dam	0·1326	0·437	0·424	,, ,,
Connell's Dam	0·0928	0·452	0·331	,, ,,
Stoney Creek Resvr.	0·0133	0·146	0·332	,, ,, } Geelong Supply
Lovely Banks ,,	0 0199	0 081	0·292	,, ,, } Geelong Supply
Geelong Supply	0·0006	0 013	nil	1877
,, ,,	0 0009	0·007	,,	,,
,, ,,	...	0·0046	,,	,, Lovely Banks Resrvr.

Art. II.—*Photography: Its Past and Present.*

By Ludovic Hart.

[Read 14th May, 1885.]

Art. III.—*On the Recent Earth-Tremors, and the Conditions which they Indicate.*

By G. S. Griffiths.

[Read 11th June, 1885.]

The Earthquake of 13th May, 1885.

It having grown apparent to every one that the earth's crust in the vicinity of Tasmania has lately, from some obscure cause, become unstable, I have collected all the notices of the last shock which I could obtain, and have examined them with a view—first, to discover the precise seat of seismic activity; and, secondly, to determine the character of that action. If the evidence available enables us to accurately diagnose the conditions now prevailing below Bass's Straits we may be able, in some degree, to anticipate the immediate seismic future of those regions.

I have obtained a record of over forty observations, but as some of these are obviously inexact, I have had to exclude them from consideration, retaining thirty-five for examination. Of these, nineteen come from Tasmania, four from New South Wales, and twelve from Victoria. To facilitate comparison I have, in every case, reduced the local time to that of Hobart.

TABLE OF OBSERVATION.

Victoria.

Place.	Local Time.	Hobart Time.	Duration.	Direction. (N / W+E)
Melbourne	... 9·28	... 9·38		
Beechworth	... 9·30	... 9·40		
Wilson's Prom.	... 9·27	... 9.37	... 0′ 45″	... ↤ ↧
Warragul	... 9·31	... 9·41	... 0′ 40″	
Flinders	... 9·30	... 9·40		

VICTORIA.

E

PLACE.	LOCAL TIME.	HOBART TIME.	DURATION.	DIRECTION.
Geelong	9·27	9·37	0′ 20″ to 0′ 30″	←
Bairnsdale	9·20	9·30	0′ 3″	←
Bruthen	9·28	9·38	1′ 0″	
Foster	9·30	9·40	0′ 50″	→
Buchan	9·28	9·38	3′ 0″	
Omeo	9·28	9·38	0′ 20″	↗
Sale	9·30	9·40		↓

NEW SOUTH WALES.

PLACE.	LOCAL TIME.	HOBART TIME.	DURATION.	DIRECTION.
Bega	9·55	9·40	0′ 40″	
Albury	9·55	9·40	0′ 30″	
Bombala	10·5	9·50	1′ 0″	↑
Gabo	9·50	9·35	1′ 0″	↑

TASMANIA.

PLACE.	LOCAL TIME.	HOBART TIME.	DURATION.	DIRECTION.
Hobart	9·37	9·37		
Launceston		9·37		←
Sandhills		9·35		↙
East Coast		9·35		
Scottsdale		9·36		
Corinna		9·45		
Fingal		9·35		↙
Springbay		9·30	3′ 0″	→
Cressy		9·40		
Circular Head		9·40	0′ 30″	
Low Head		9·30	0′ 50″	
St. Leonards		9·40		
Beaconsfield		9·37		
Longford		9·37		
Westbury		9·33		
Deloraine		9·35		
Campbell		9·40		
Georgetown		9·40		
Moorina		9.45		

An examination of the table reveals several discrepancies as to time which detract from its value. For instance, Flinders reports the shock at 9·40, although Geelong, some 50 miles further away from the focus, notes it at 9·37, or three minutes earlier. But the Wilson's Promontory report also gives 9·37, so that there is the same discrepancy of three minutes between the neighbouring stations of Flinders and Wilson's Promontory. Again, it is strange that Geelong and Wilson's Promontory, 120 miles apart, should both note it at the same moment, when between Sale and Bairnsdale on the same co-seismic lines, there is a difference of ten minutes.

I have sought to reduce the minor errors of observation by ascertaining the mean time of the record of each colony, and this method gives more intelligible results.

TABLE OF MEAN TIME.

Tasmania	9·38
Victoria	9·38-81
New South Wales	9·43

From the first table we learn that the shock was felt simultaneously at Gabo and on the east coast of Tasmania, the time being 9·35.

The wave passed from the coast of Tasmania to Launceston (a distance of 55 miles) in two minutes; from Launceston to Circular Head (110 miles), in three minutes, reaching the latter place at 9·40.

The accepted method of determining the seismic centre is to group together the localities whose records synchronize. These will be found to arrange themselves in curved lines, and the whole series of these curves will form more or less perfect concentric circles, within the innermost of which lies the seat of disturbance.

This method gives us Gabo and the east coast of Tasmania as points on inner circle; time, 9·35. The next ring yielded by the reports cuts Launceston, Hobart, Wilson's Promontory, Geelong, Melbourne, the Buchan, and Omeo, at 9·37-9·38; and, still further from the centre, the wave, at 9·40, strikes Cressy and Circular Head in Tasmania, Beechworth and Warragul in Victoria, and Albury and Bega in New South Wales. The outermost ring seems to be recorded at Bombala, N.S.W., at 9·50.

A glance at these rings shows that they are asymmetric, from which we judge that the earthquake wave travelled outwards at unequal speeds, and we have other evidence to show that the speed of a tremor varies with the elasticity of the medium. Mallet's experiments showed that the shock caused by blasting travels through wet sand at the rate of 951 feet per second; through friable granite at 1283 feet per second; and through solid granite at 1640 feet per second. The rates of speed recorded in Europe are various, but the maximum speed is 33 miles per minute. The rate of the Calabrian earthquake, of 1857, was 8 miles per minute in one direction, and 11 miles in another. That of Viège, 1855, was 33 miles to the north, and 14 miles to the south. The central European earthquake of 1872 recorded 27 miles per minute, and that of Travancore, E.I., was but eight miles.

The rates noted here at the earthquake of the 13th May vary very much, and some are extraordinarily high. From the east coast to Launceston the rate was 27 miles per minute; from thence to Circular Head, 36 miles per minute; from Wilson's Promontory to Beechworth, 63 miles; from Sale to Warragul, 66 miles; and from Omeo to Beechworth, 30 miles. On the other hand, from Gabo to Bombala the rate was only 7½ miles per minute. It is very doubtful whether all of these records can be relied upon. Nevertheless, we have a mass of evidence to justify the belief that the speed of the tremor in some parts may have been double that of the shocks noted elsewhere.

The direction of the wave varies with the locality: thus in Tasmania it was from east to west; in New South Wales it was from south to north; and in Victoria it was from south-east to north-west. These lines all converge upon the seismic centre which we have already determined.

The duration of the shock varied from point to point, being from three seconds up to three minutes. In this fact we have evidence that more than one rupture occurred. For, if there had been but one, the length of the resultant tremor would have been everywhere proportioned to the one movement. The duration of such a tremor might indeed be expected to increase regularly with the distance, for an earthquake is compounded of two dissimilar movements, the one longitudinal and the other horizontal, and these two motions travel at different rates of speed. Consequently, as the distance traversed increases, the two motions straggle apart, and the effect is that the vibrations are spread over a period which lengthens as they travel outwards. But the duration of the recent tremors varies most eccentrically. It does not increase as the focus is left behind, nor does it diminish regularly in any one direction. The nearest approach to uniformity is noticed in the vicinity of Cape Howe; for at Gabo, Bombala, Bruthen, and Foster, the time was from fifty to sixty seconds. The only conclusion tenable is that there were distinct movements at various distant points. And this conclusion harmonises with the view that ruptures took place simultaneously at the centre of the disturbed area and around its margin.

The effects of the shock were most violent in Tasmania. Walls cracked, plate-glass windows were shivered, stacks of wood and bricks toppled over, trees swayed, church bells tolled, boulders started from their beds, while men left their houses, and flocks of sheep scattered in affright. A church finial broke off and fell to the eastward; another one was shifted half an inch in the same direction, and the débris of the chimneys lay along the ground in an easterly and westerly direction. The pendulum of a seisometer swayed half an inch, and other instruments indicated a horizontal movement of 0·05 inch, and a vertical of 0·112 inch, and water in a sawpit oscillated two inches vertically. The shock was felt in the underground workings of two mines.

In Victoria the locality most strongly shaken was Wilson's Promontory, but the movement was severe at Geelong, Warragul, and Bairnsdale.

It was generally reported that the motion was greatest in lighthouses, belfries, and wharves, and least on terra firma.

Every earthquake takes three phases, as it affects the land, the sea, or the air. The land shock we have described. The sea shock has not been recorded in its entirety; it consists of two waves, and of these the second has not been noticed by the observers. At Beauty Point, in Tasmania, a tidal wave was reported. In the Esk the waters grew discoloured, and at the Sandhills they were agitated. These disturbances coincided in time with the land shock, as far as I can learn, and this was to have been expected; but the characteristic second wave, which should have followed, has not been noted. Its absence may be accounted for in three ways—firstly, by the dulness of the observers; secondly, by the circumstance that the shores of Tasmania generally have deep water round them, and that where this is the case, the sea surface simply rises and falls, which movement might not attract attention. But where the beach is shelving, as it is at the entrance to the Gippsland Lakes, on the Ninety-mile Beach, a roller is formed, which would be more notable. Mr. Quail, the pilot, tells me that nothing of the kind was noticed there by him, although he was on the beach when he felt the shock, and simultaneously saw the sea agitated in an unusual manner.

Thirdly, it may be explained by supposing that the disturbed area was so close to the coast that the second wave must have arrived as soon as the first, or so quickly after it as not to have been distinguishable from it. The secondary sea wave of an earthquake travels more slowly than the first. On the occasion of the Lisbon earthquake, the first wave reached Madeira in 25 minutes, but the second took $2\frac{1}{2}$ hours, the rates of speed being as 6 is to 1. If the seismic centre of the recent shock was 120 miles distant from the coast, and the speed of the tremor was 30 miles per minute, the secondary wave would reach the shore 20 minutes after the first, and this ought to have been noted somewhere. But if the distance off shore was only 30 miles, the secondary wave would arrive within six minutes after the first.

The conclusion I come to is, that the edge of the seismic centre was close to the east coast of Tasmania and to the south-east extremity of Australia.

The last form of manifestation to be considered is the air wave, which reveals itself by loud rolling rumbling sounds, as of heavy-laden waggons. Such reverberations, loud and long-continued, were noticed in innumerable places.

I have now set out all the facts known to me concerning the recent earthquake, and I have founded certain conclusions upon them. A comparison of times and places and directions of the shock indicates that the seismic centre must have been about the point intersected by 150 E. long. and 40 S. lat. The high angle of emergence at the Sand-hills, Tasmania, where boulders were ejected from their beds; the high speed of the land tremor, and the absence of a second sea wave, all point to the margin of the disturbed area having been much nearer to the land than the focus. The high speed of the tremor again points unmistakably to a deep focus. For it is known that the speed of the wave of elastic compression is greatest when it traverses rigid strata, and that it slackens in decomposed, faulted, or friable rocks. The wave could have attained to the high rate reported locally only where are extensive masses of unbroken, homogeneous, crystalline rocks. To obtain a free course through strata of this character the wave must have emanated from a point situated low down in the outer crust. The greatest depth at which such movements can occur is believed to be 30 miles, and most earthquakes originate at depths of from 8 to 15 miles. I am of opinion that, with ours, the latter distance must have been the minimum depth. The exact depth of the focus can be calculated by observing the mean direction of the rents in the walls of buildings, and I regret that I have no data of this kind to offer.

The next feature in connection with this earthquake which I shall point out is that the seismic activity has returned with the winter season. The previous shock occurred in June of last year. The records of the northern hemisphere show that three-fifths of the whole number of earthquakes there occur in the winter season, and it is interesting to see that the connection with that season is maintained in this hemisphere.

Another interesting circumstance is that the focus occurs within an area of high barometric pressure, as is well shown by the weather chart of that date. The isobar of 30·2 surrounds it, and that of 30·3 overlies Bass's Strait. Volcanic disturbances increase with a low barometer; with us the converse has occurred, and this fact is important when we are investigating the causes of the recent tremors.

II.

Having described the features of this earthquake, I will proceed to consider what are the subterranean conditions which they indicate. An earthquake is the result of an earth-rupture, and an earth-rupture is caused in three different ways. It may occur through the contraction of the globe, due to loss of heat, during which secular process the inner cooling parts shrink away from the cold solidified external shell, which latter part nevertheless clings to the retreating nucleus under the indraught of gravitation. This crust, ever contracting, and yet ever too large, unceasingly adjusts itself to the dwindling core by buckling up along certain lines, and then cracking along the folds or anticlinal crests. The ruptured edges, pressed together, stack up their shattered strata into mountain chains. In other words, mountains are the result of the crumpling and piling-up of broken strata under the pressure of a tremendous tangential thrust, but the process is a very slow one, characterised by an infinite number of minute movements, small fractures, and slight shocks, and a limited number of large displacements and violent shocks.

It is then possible that the series of tremors to which the last earthquake belongs indicates that such an operation is in progress under foot, and, if so, it may have been going on, intermittently, for ages past, and it may last for ages to come. But if it has been so we ought to see its superficial effects in the shape of chains of mountains occupying certain determinate lines, and the plains upon which they stand increasing their height relatively to the sea-level.

Let us test this hypothesis by applying it to the present case.

A tract, the centre of which is near to 150° E, and 40° S, has been undermined by the shrinking of the subjacent strata. As fast as the shallow cavity is formed, the suspended stratum crushes down into it, simultaneously sending outwards in all directions, and with every move, tremors of varying intensity; for it cannot be supposed that the hardest rock, however thick, is rigid enough to withstand long the forces of gravity acting on it, directly, through its own mass, and, indirectly, through that of the overlying ocean and atmosphere. Of the latter two elements, the atmosphere is probably the more potent crushing agent; for the ocean is a fixed dead-weight, and cannot try the tenacity of a stretched stratum in the same degree as the pressure of the unstable lively atmosphere does. The difference between the weights indicated by a high and a low barometer is very great. Two inches of mercury represent a pressure of 2,000,000 tons to the square mile; a fluctuating barometer, therefore, means the fluctuation of enormous pressures. The atmospheric waves as they dance on and off the rocky floor must cause it to spring again, like the scaffold plank undulating under the hodman's foot, the cohesion of its particles lessening with every vibration, until at last a higher air-wave than usual crushes down the weakened mass. Looked at from this point of view, the presence of an area of high pressure over the seismic centre, at the time of the shock, becomes significant; and as volcanic activity is repressed by a high and promoted by a low barometer, this evidence tells as much against the theory of the volcanic origin of the shocks as it does in favour of their being due to secular contraction.

The mass having now sunk, under pressure, to a lower horizon—one nearer to the earth's centre—it has to pack into a space too small for it. Consequently the margins of the area cannot sink equally with the main body. The lips opposed to each other appear to rise because all the adjacent parts fall. In actual fact, mountains have been but little elevated; all around them has been lowered, till they stand up prominently, and they mark to-day the sea-level of a past epoch.

The area itself now begins to assume the appearance of a squeezed ice-floe, with its turned-up rim and sunken centre. In the course of ages this slow piling up of the crushed contorted edges, and this gentle depression of the more level but still fractured and flawed body, have created pronounced physical features within the area under notice. Mountains fringe it throughout an arc of over 200°, running parallel with the co-seismal lines which I drew upon the map. They rise at right-angles to the path of the earthquake wave, which is just where we should look for them. They traverse Tasmania with a meridianal axis; they run N. E. from Wilson's Promontory, and S. W. from Cape Howe. The platform beneath this ring of mountains is rising also. The coast of Victoria has risen within recent times. It has been calculated that only 1400 years ago sea waves played over the Flemington race-course, and fretted the base of Flemington hill. About the same period St. Kilda was a promontory jutting out between two shallow bays, one of which covered the site of Albert Park, and the other that of the Elwood swamp. Brighton was under water. Frankston was cut off from Cheltenham by a strait which united Port Phillip with Western Port. A little earlier all the Gippsland lowlands were submerged up to the foot of the ranges. I can speak less confidently of the movement in Tasmania, but I learn that there are raised beaches on the banks of the Derwent, to tell of a receding ocean.

Although I cannot say that the recent shocks have travelled to New Zealand, it is well to remember that the west coasts of these islands have risen, in parts, 9 feet during the last forty years, and a ship wrecked in 1814 now lies 200 yards inland. I have not heard that the seafaring people of our coasts have noted any changes in the sea marks, but the officers of vessels traversing Bass's Straits believe that the waters are shoaling.

It is probable that the west coast of New Zealand supplies the easterly rim of the sinking area, while on the N. E. a submarine ridge connects New Zealand with Australia, and supplies another segment of the margin. The floor of this scallop-shaped depression is 15,000 feet below the sea-level, and the focus of the last earthquake shocks is located beneath an ocean 12,000 feet deep. Here then we have the area of subsidence which this hypothesis requires.

If the recent shocks have been due to such conditions as these, it would be likely that ruptures would occur almost simultaneously at the depressed centre, and around the mountain margin. If such has been the case it would account for the apparently very high rates of speed, and explain many discrepancies in the time-record, such as the synchronous shocks at Wilson's Promontory and Beechworth, places on different seismal circles.

I have stated that there are two other conditions under which the earth's crust can be ruptured, and the surface shaken. Both of these operations are superficial and local in their effects, and both are connected with volcanic action. The time at my disposal will not suffice to discuss their applicability to the present case, and I will not stop to describe them, as I consider that the conclusion best justified by the phenomena recorded, is that the shocks are due to secular shrinkage of the earth, this giving rise to the fracture and distortion of the region about and below us, with a depression of the sea-bed to the east of Tasmania, and a slow elevation of the S. E. of Australia, and perhaps the west coast of New Zealand.

ART. IV.—*The Atmosphere a Source of Nitrogen in Plant Economy.*

BY E. LLOYD MARKS.

[Read 11th June, 1885.]

Art. V.—*Notes on some Evidences of Glaciation in the Australian Alps.*

Article I.

By James Stirling, F.L.S., F.G.S.

[Read 9th July, 1885.]

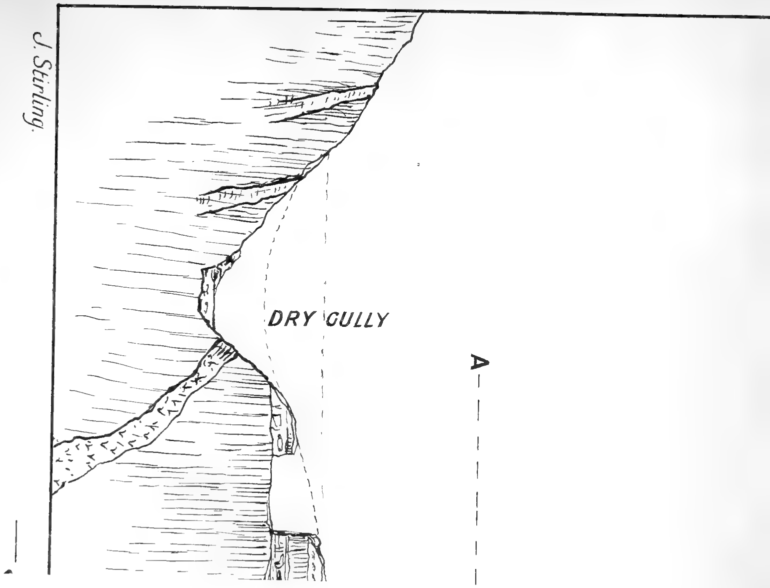
On examining a map of Victoria, it will be seen that the watershed line of the main Dividing Range is deflected south-easterly from Mount Hotham, round the sources of the Livingstone Creek, forming a somewhat parabolic curve. It is in this area that the evidences of glaciation herein described are to be seen, consisting of the following:—

1. Grooved, striated, and shattered rock surfaces.
2. Heavy transported boulders, bouldery wash-clays, and auriferous gravels.
3. Erratics and morainic débris.
4. Glaciated contour of country and eroded lake-basins.
5. Roches moutonnées.

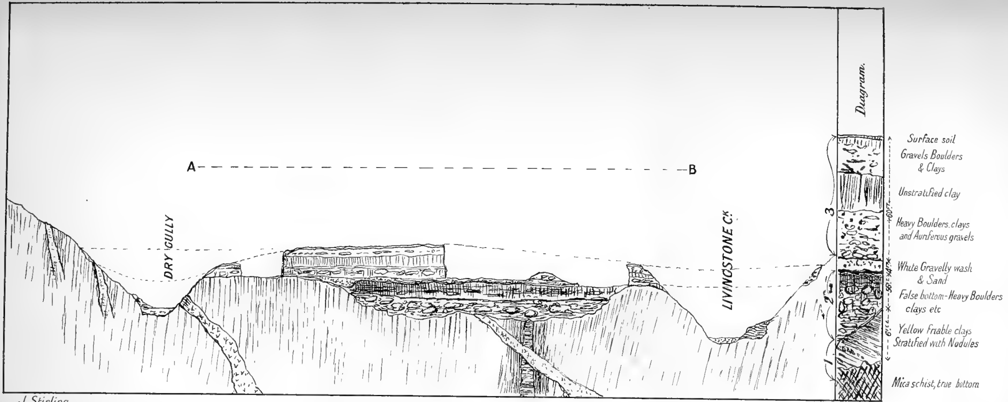
In the following pages I have endeavoured to describe the various phenomena which seem to me to represent the evidence of glacial action, giving in some instances rather detailed geological descriptions, which, independent of the glacial evidences, may prove interesting as supplying information of a scientific character of this little-known area. I have described each valley separately, in order that a clearer picture of their physiography may be produced. These valleys comprise the Victoria River, Livingstone Creek, and the Benambra Creek, the latter margining the Omeo Plains; but in the present article I confine my remarks to the two former.

Victoria Creek Valley.

Rising in the Paw-Paw tableland on the main Divide, at an elevation of 5000 feet above sea-level, the Victoria Creek has eroded its present channel—first through the



where outcrops of silurian slates are found, and where the



J. Stirling.

— SECTION ACROSS DRY HILL – near OMEO —
— *Scale: Vertical 100 feet to 1 Inch* —
— *do Horizontal 8 chs. to 1 do* —

tertiary basalts, and then into some hard crystalline (gneissose) rocks. Unlike many other streams which have cut their way through these old lava flows—notably, the Dargo River—there are no bold escarpments of pentagonal basaltic columns, but the sides of the valley have been planed down in uniform slopes, presenting rather an undulating appearance for the first four or five miles. At lower levels, the hard gneissose rocks are seen to be planed and rounded in the direction of the main valley, giving to them a moutonné appearance. On examining the surface of some blocks standing out from the black peaty soil in the narrow sub-alpine flats, their surfaces are seen to be striated by parallel groovings in the direction of the valley, viz., east and west; and that these markings cut the strike of the bedding of the rocks at an angle of 25° to 30°, the latter being 60′ to 65′ N.W. At a point lower down (not more than half-a-mile distant), the watercourse has eroded a channel through a somewhat narrow gorge, the steep rocky spurs on each side being composed of gneiss and other coarse micaceous schists. At various points of low spurs, masses of red earth, in which are angular fragments of metamorphic and basaltic rocks, are found, and generally at heights varying between twenty and thirty feet above the level of the present watercourse. About six miles lower down the valley widens, and a good depth of alluvium forms some open flats known as Parslow's Plains. On examining some superficial detritus on the hill-sides overlooking the flat to the north, remnants of yellow indurated clays, similar to those at Cobungra, are found. These laminated clays have evidently been brought from old miocene river beds similar to those at the sources of the Cobungra, some twelve miles distant, and at the higher levels. The fact of finding these fragments here seems to me sufficient proof that they were not washed down by the translocating agency of running water, otherwise it seems hardly possible that these clays would not have been long since worn by attrition to fine powder or sediment. In the creek bed which winds sinuously through the Parslow's Plain are masses of large waterworn boulders of basalt, some of which are flattened on one side, and striated altogether distinct from ordinary weathering or the action of running water. At lower levels, the Victoria receives an affluent from the south called Spring Creek, which rises at the Dividing Range near Mount Phipps, where outcrops of silurian slates are found, and where the passage from unaltered slates to completely metamorphosed schists may be well seen—the slates occupying the fall towards the Dargo River, and the crystalline schists that of the Victoria Valley.

This creek traverses generally well-timbered pastoral country, the geological structure composed principally of metamorphic schists, which are penetrated by numerous diabasic, dioritic, and porphyritic dykes. At various bends in the valley, where it narrows, masses of water-worn shingle and igneous boulders are seen associated with what is evidently a morainic débris of metamorphic schists, igneous dykes and granite, left probably by a retreating subsidiary glacier which once filled the valley. The watershed being so small, there does not seem to be any possibility of running water having deposited these masses of débris in the situation where they now occur. At the junction of the two streams some of the more dense boulders of andesite are seen to be striated in a similar manner to the specimens, No. 1, now exhibited in illustration of this paper. About two miles further on—below Parslow's homestead—several small water-courses enter from the south: the principal of these from a locality known as Victoria Plains, a natural ice-scooped basin in the valley to the south, presenting on the whole a distinctively moutonné aspect. It was Victoria Plains that the Vice-Regal party, accompanied by the Surveyor-General and late Secretary for Mines, passed through en route from Omeo to Bright, and the scenery of which is so eloquently described in their narrative, page 38, of "Physical Resources of North Gippsland," that I cannot refrain from quoting it, as follows:—"We diverged from our path in order to see Victoria Plains; we saw it with the afternoon sun on it. It is not flat, but slightly undulating; it is in the form of long, low smooth banks or ridges running parallel to each other, with hollows not so deeply sculptured as to become watercourses. The lights thrown across the furrowed surface, gilding the low ranges and leaving the hollows in shadow, lent a beauty to this sequestered spot which under other circumstances it might not present; set in a frame of forest, itself destitute of timber and richly grassed, it made a picture altogether strange and startling, entering upon it as we did suddenly and with no idea of the character of the landscape which was to open to our view." The smooth banks or ridges—sowbacks—above referred to are, I think, clearly due to glacial abrasion. An examination of the boulders and débris at the lower levels where the valley narrows and where the watercourse has cut through a hard bar of quartz-porphyry and dense gneiss, tends to confirm this impression, revealing other evidences in the shape of striated boulders of yellow felsitic (micro-porphyritic) dykes on the hill-sides. A few miles below this point the Victoria Valley suddenly narrows (the hills on either side rounded and planed down), and the watercourse falls into a deep gorge towards the Cobungra River. The elevation of Parslow's Plains is 3000 feet above sea-level. On considering the evidences of glaciation in this valley, I think we are justified in inferring that the Victoria and Spring Creeks, together with the sub-alpine basin at Parslow's Plains, was occupied by large masses of ice during later Pleistocene times. The great amount of erodation which has taken place elsewhere, notably in the Dargo River valley, on the southern side of the main Dividing Range, is in striking contrast with the small amount visible in the upper sources of the Victoria Creek, where denudation has been less active. These valleys would to a great extent be sheltered from the influence of northern or north-western hot winds by the high Bogong Ranges, while the Dargo is open to the more constant precipitation of south-west and south moisture-laden winds, so that long after the maximum of glaciation had occurred the valleys of the Victoria Creeks would retain their icy mantles.

Livingstone Creek Valley.

Embracing an area of 138 square miles, with a total length of 31 miles, this valley slopes uniformly from the open moorland flats near its sources, in the main Divide, to the Hinnomunjie Flats at the junction with the Mitta Mitta River. The elevation of the Dividing Range at the sources of the Livingstone Creek is 4500 feet, and of the Hinnomunjie Flats about 1800 feet. The typical silurian slates and sandstones of the goldfields occupy the southern crest of the Divide and the fall towards the Wentworth River. About six miles further south, in the valley of the latter, are extensive outcrops of a grey quartz conglomerate and coarse gritty sandstone, to be hereafter referred to.

On the northern crest of the Divide is a mass of grey ternary granite, which gives place to the metamorphic schists and intrusive dykes which make up the formation of the Livingstone Creek Valley. Following the creek downwards from the upper moorland flats, which vary in width from 40 to 100 chains, the valley narrows by the near approach of high lateral spurs of contorted mica schist, which in some cases is seen to be intruded upon by masses of quartz-mica diorite. About seven miles from its source, the Livingstone receives a tributary from the east (New Rush Creek), on which are situated some gold workings in heavy auriferous gravels and bouldery wash; many of the boulders are striated and exhibit flat surfaces. On the margin of the raised flats, at the junction of the two streams, are masses of angular detritus in a stiff clay, together with large waterworn boulders and blocks of the quartz-mica diorite of the higher levels, and also some rounded boulders of quartz conglomerate similar to those in the Wentworth Valley, and which, so far as known, do not occur *in situ* in the Livingstone Creek watershed, but which are distributed along the latter to lower levels, and are to all appearance erratics. Some large flattened quartz boulders are also seen similar to the mass which outcrops on the main Divide some twelve miles distant (to the east), viz., at the New Rush Creek. From this point the ranges forming the eastern watershed of the Livingstone are more undulating and lightly timbered, while on the west, high, bold, wooded ranges rise rather abruptly in steep spurs from the creek flats to an elevation of 4000 feet. Near Mount Livingstone—a bold, rounded peak south-west from Omeo—the Livingstone Creek receives an important affluent from the west. This affluent—Jim-and-Jack Creek—although it traverses a rock-bound gorge, where it flanks Mount Livingstone, yet opens out into some richly grassed upland flats and rolling pasture hills, with outcrops of grey, crystalline rocks (gneiss) on the points of the undulating spurs, which show faint traces of striation in the direction of the valley. A low gap separates this area from Parslow's Plains, previously described. At various points in the rocky gorge of the lower part of this stream are rounded hillocks, generally at the termination of spurs at an angle or trend of the valley. They are seen to consist of masses of waterworn boulders in a stiff, tenacious clay, capped generally with gravels of later date. From the junction of Jim-and-Jack with the Livingstone Creek, the latter has eroded its present channel through recurring masses of boulder clay and auriferous gravels, and heavy transported boulders, &c., for five or six miles to the township of Omeo. It is interesting to note the geological structure of Mount Livingstone in connection with the superficial accumulation of boulders, clays, and gravels at its northern base. The northern spurs and crest of the mountain are made up of bands of mica schist, nodular argillaceo-mica schist, quartzitic schist, intersected by numerous diabasic, dioritic, and porphyritic dykes; and the southern slopes, towards Jim-and-Jack Creek, consist principally of gneiss—gneiss passing into metamorphic granite, with broad dykes of brownish quartz-porphyry and granitite. To the east of Mount Livingstone, the country is more open and undulating for about six miles, until the thickly timbered and steeper rocky spurs from the Great Dividing Range are reached. This lower area of undulating ridges and rounded hills, which constitutes the settled area near Omeo, is intersected by several small watercourses, most of which exhibit what appears to be very distinct evidences of glaciation. One in particular, Deep Flume Creek, contains numerous groovings and markings on the rocky outcrops where the surface soils have been removed on its southern slopes. The creek runs westerly to its confluence with the Livingstone, while the markings are persistently northerly, and vary in diameter and depth from furrows six inches deep and nine inches wide to fine markings—scratches like those made with a sharp instrument. They are also continuous for ten or twelve feet, and cut the strike of the rocks on which they occur. The latter consist of mica schists, hornfels and gneiss; while at higher levels, on the hill-side, màsses of an intrusive quartzite are seen to be planed and smoothed down in the direction of the lower markings, viz., that of the Livingstone Creek Valley. In many places, masses of clay and angular débris still cover the markings, while at higher levels the spurs and ridges are capped with gravel. Another creek, Day's Creek, which enters the main stream near Omeo, has on its eastern slopes a rounded hillock, which is abraded and worn down by glacier action; for a hard hornblendic diorite dyke on its northern face is grooved and striated, also in the direction of the Livingstone Creek Valley. The lower courses of this stream have cut through the old lake-bed at Omeo, which extends from Jim-and-Jack Creek, previously described. Another watercourse, Wilson's Creek, which enters from the same side as Day's Creek, opens out into two branches, each taking its rise in the Dividing Range to the east of Omeo. Along their present courses deposits of heavy waterworn (dyke stone) boulders are frequent, some of which are beautifully striated, particularly the diabase and microporphyrites; while on the points of rocky spurs on its northern slopes are some distinct groovings at an elevation of sixty feet above the present creek bed. On the opposite side of the Livingstone Creek, where this creek joins it, is a deep hollow, worn to a lower level than the former, and filled with immense masses of igneous basaltic rock (large waterworn boulders), many of which exceed eight feet in diameter. These are overlaid by smaller boulders of the various igneous and metamorphic rocks of the valley in a stiff clay, with occasional thick deposits of pipe clay and auriferous gravels. The bed rock is shattered and broken, and in some places rammed with hard quartzose and igneous boulders of smaller dimensions for a foot below the surface. In following the creek upwards from this point these immense igneous boulders are seen to form a continuous line for fully 100 chains (where exposed by the gold workings), and seem to me to represent the products of a lateral moraine extending from Mount Livingstone, where a large glacier filled the valley. A short distance up the creek from this point, where the road to Bingomunjie leaves the Livingstone, a very large mass of andesite igneous rock, fully ten feet in diameter, and with the lower side flattened and planed down, is seen to rest on a friable yellow clay, the latter crammed with angular and rounded rock fragments—a veritable still, the igneous boulder being surrounded and overlaid by auriferous gravels, bouldery wash and clays. A mile higher up, on the eastern margin of these deposits, and also on the east side of the Livingstone Creek, is situate the township of Omeo. The gold workings *in situ* afford excellent means of studying the relation of the different materials filling up the old lake-bed. The section across these deposits at Dry Hill, about a mile west from Omeo, is given. These deposits have been cut through by a small western affluent—Dry Gully. There is a basin-shaped hollow near its source, below some auriferous quartz veins, which is also filled up with a deposit of heavy boulders, clays, and auriferous gravels, known as Power's Gully, at an elevation of 900 feet above the Dry Hill area.

Following the Livingstone Creek downwards from Wilson's Creek junction the hills on each side are more or less planed down in flowing outlines, while masses of dense grey gneiss, which outcrop on the hill-sides, are in some places polished and striated, presenting a moutonné appearance. Three miles lower down, another depression, or old lake-basin, called Hinnomunjie Swamp, is reached. Here are seen deposits similar to those at Dry Hill, while the adjoining hillocks are abraded in rounded undulatory outlines. Still lower, at the junction of the Livingstone with the Mitta Hinnomunjie Station flats, is another basin filled with similar materials. The present course of the Livingstone seems to have eroded its channel in some places quite out of the courses it assumed in Pliocene times, notably between Wilson's Creek and Hinnomunjie Swamp, and between the latter and Hinnomunjie Flat, where the Pliocene river-bed was more to the westward, under the steep ridges proceeding from Mount Bingomunjie range.

From the evidences supplied by the various markings, the heavy bouldery deposits, and what I believe to be heaps of morainic débris in the Livingstone Creek valley, I think it is highly probable that we have here represented at least three interglacial periods since Pliocene times.

1. The deposits of friable, yellow, unstratified clays, as well as that containing the small angular and rounded fragments, seems to me to represent the remnants of a once more extensive moraine profonde, which was the product of the first period of a very extensive area of glaciation during Pliocene times; whether such period of refrigeration be due simply to elevation of the land surface, as suggested by Professor Tate,* or to more complex cosmic and terrestrial causes—such as changes of eccentricity of the earth's orbit; the occurrence of summer or winter in aphelion, in conjunction with the slower or more irregular changes of geographical conditions—these combined causes acting chiefly through the agency of heat-bearing oceanic currents—and of snow and ice collecting highlands, as suggested by Prof. Wallace†; or to the theory of variation of heat of the sun, as advanced so ably by Prof. Siemens, and referred to by Mr. Searles V. Wood, F.G.S. ‡—viz., that

* Anniversary Address, Adelaide Philosophical Society, p. 27.
† Island Life, p. 484.
‡ On the Newer Pliocene Deposits of England, Q.J.G.S., Vol. 38, p. 737.

the heat of the sun is maintained by the combustion of gases diffused in the medium through which it moves, and which are drawn in at the polar and, after combustion, returned by centrifugal force from the equatorial parts of the sun into space.

Extensive sub-aërial denudation and a warmer climate succeeded the breaking up of this first period of Pliocene glaciation. Another, although less severe, refrigeration took place, culminating in a second glacial period, during which the surface contours of the more prominent low-lying ridges near Omeo were greatly abraded, and during the latter part of which the heavy boulders of the Dry Gully, &c., false bottoms were deposited, as well as the erratics and blocs perchés of the Livingstone Creek valley. This was followed by a period of comparative repose, when sub-aërial denudation was slower and less active, a warmer and more equable climate prevailing. During this time the pipe-clays, white gravelly wash, and sand-beds overlying the false bottom at Dry Gully were deposited in the still icy waters of this ancient mountain tarn. The fragments of fossilised wood in the above deposits would also seem to prove that the surrounding ranges were covered with a luxuriant timber vegetation of myrtaceous genera, probably forms allied to Eucalyptus Pluti. A third and final period of glaciation occurred, less extensive than either of the preceding, at the breaking up of which the auriferous gravels, clays, and boulders of the Livingstone Creek were deposited, and also the finer gravels on the ridges near Omeo and along the spurs abutting on the Livingstone Creek. The whole of the present surface configuration on the undulating ranges near Omeo, the Victoria Plains, and Jim-and-Jack Creek, seems to me to have been originally moulded by ice action; indeed, unless we accept the hypothesis of glacial abrasion, it seems difficult to account for the rounded and flowing outlines in a rock formation which elsewhere under sub-aërial influences presents surface contours bristling with craggy peaks and rugged surfaces. I have elsewhere* sought to explain this peculiar feature of the ranges in the Livingstone Creek valley, and in the other sources of the Mitta Mitta, by differences in the amount of rainfall and the slower degrading influences of frosts and snows; but on viewing the orographical features in the light which the

* Physical Features of the Australian Alps, Trans. Roy. Soc., Vict., Vol. XXI.

glacial evidences afford in this valley, it seems difficult to resist the conviction that the present smooth outlines are mainly due to ice erosion. Another fact which seems to support this view is, that in recent times the erodation and denudation that is taking place under sub-aërial conditions presents sharper and more rugged outlines in the sides of the gullies and creeks.

In an inquiry into the causation of these ancient mountain lakes or tarns, we may consider three different hypotheses—

1. That they were caused by oscillations of the level of the surface, such as that produced by faultings and other dislocations, and consequently might be pre-glacial.
2. That they were formed by the erosive action of glaciers.
3. That they were formed by the building up of terminal moraines at the close of, or during, a glacial epoch.

The first of these propositions in a district which has been subjected to violent convulsions, such as that occupied by portion of the Mitta Mitta source basin, may appear possible. For at Day's Hill—a rounded elevation situate near Omeo, and at the lower extremity of the old lake-bed—there is an intrusive mass of granitoid rock, which has sent out numerous radiating dykes of felso-porphyrite and quartz porphyry; while associated with the former are massive outcrops of quartz. One of these quartzitic outflows, or intrusions, crosses the lower end of the lake-bed near Wilson's Creek junction, and might have caused the barrier to the discharge of the upper valley at this place if it had been intruded subsequently to the excavation of the latter; but, from the geological surroundings, these intrusions are contemporaneous with the larger intrusive mass at Day's Hill, which *à fortiori* is regarded as probably Devonian, and consequently intruded long prior to the excavation of the Livingstone Creek valley. Faultings of the metamorphic schists in this valley are plentiful enough; yet no such dislocation of the surface has yet been found at those points where they might be considered to have produced a depression or elevation resulting in the formation of existing lake-basins. It must not be forgotten that eminent geologists in examining those districts elsewhere, where similar geological conditions exist, and where probably similar climatic influences prevail, such as the highlands of Scotland (the land of breaks and faults), have remarked that instances where a fault could be said to be even a proximate cause of a lake-basin are extremely rare, if any at all exist; while numerous instances have been given of Scottish lochs having been scooped out by the erosive power of glacial ice in unbroken strata. It does not appear probable that the origin of the Livingstone Creek old lake-beds is to be ascribed to any pre-glacial earth movements.

2. That they were scooped out by the erosive action of glaciers is more in accordance with the observed facts. The seeming difficulty in the apparent want of sufficient slope in the valley may be answered by the well-known fact, "that the slope of the upper surface of a plastic or fluid substance determines the rate of the flow, and not that of the under surface; since, if ice were accumulated over a region so that the upper surface had the requisite slope, there would be motion in the mass in the direction of this slope whatever the bottom of the slope might be. At the same time the slope of the land at the bottom or the courses of the valleys would determine to some extent the movement of the bottom."* In this case there would in all probability be a sufficient slope to allow of a proper down-thrust of the glacier mass at each of the localities previously referred to, and the consequent rasping and carving-out of the lake-beds by the harder rock fragments in the glacier bottom. I am sensible of the difficulties which beset the theory of glacier excavation on mechanical and physical principles†, but the facts observed in the Dry Gully area can be more satisfactorily explained by the theory than by any other means.

3. Should, however, the slope be considered insufficient for erosion of the hollows, there are not wanting evidences that the filling up was accelerated by the building up of terminal moraines, where subsidiary lateral glaciers joined the medial valley glacier. The heavy materials deposited at the junction of New Rush, Jim-and-Jack, Dry Gully, and Wilson's Creek are striking evidences of such. Objections may be raised to the cross markings or striæ on the sample of volcanic rock produced in illustration of the evidences referred to in this paper, that "the scratches take such a variety of directions, and occur in a manner that hardly appears reconcilable with the idea that they were caused by the passage of other materials under the grinding power of ice;" but we must remember that, "as water is always

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* Text Book of Geology: Dana, p. 224.

† Mechanics of Glaciers: Rev. A. Irving, B.A., Q.J.G.S., No. 153, p. 73.

flowing under some parts of a glacier, and much melting and relegation of ice are going on in different places, stones are liable to change their position, in which case a second set of striæ and furrows may be imprinted in a new direction. In like manner, the solid rock underneath the glacier may exhibit scratches and grooves in more than one direction; the furrows will, most of them, coincide with the general course of the valley; but as the ice in different seasons varies in quantity the direction of its motion at a given time is not uniform, so that the grooves and scratches will also vary, one set often intersecting another."* Again, it may be said that the samples of mica schist present only weathered parts along cleavage lines and at softer spots; but this objection may be met by stating that the groovings are found exactly in that position where the grinding and gouging power of glacial débris under the ice sheet would be most likely to prove effective, and that the groovings are persistent across the cleavage lines as well; and further, that no similar markings are found on similar rock masses in other parts of the valley, although exposed to the degrading influences of atmospheric agencies.

The rounded outlines of the gneissic and other metamorphic rock masses on the hill-sides may also be attributed to mere weathering; but the striations on these outcrops which cross the bedding planes and cleavage lines seem to offer indisputable evidences of glacial abrasion. They occur also at what was probably the mean height of the latest valley glaciers—*i.e.*, along the margin or edge of the latter.

It must not be forgotten that the evolution of the existing contours of the Australian Alps during tertiary times was dominated over large areas by the violent volcanic outbursts which occurred in early Pliocene times. The immense sheets of basalt which now form the Dargo, Bogong, and Paw-Paw Plains—the latter at the head of the Victoria River, and which sealed up the Miocene river-beds—are striking evidences of the volcanic activity of that time; while the deep valley of the Dargo River, some 1500 feet below the Miocene river-beds, is still more striking evidence of the enormous erosion which subsequently took place in that valley.† Mr. Murray, our able Government geologist, has informed us‡

* Lyell's Geology, p. —.
† Southern Science Record, 1885, p. 12.
‡ Geo. Sur., Vict., Vol. VI., p. 41.

that "it is probable that the outlines of all the main drainage courses of the tertiary period, whether Miocene or Pliocene, were formed early in the former epoch . . . No submergence below the sea to an elevation exceeding 900 feet above the present level appears to have taken place during or since tertiary times. Had there been no lava flows, the general course of the rivers above that elevation would have remained unaltered until the present day." So that the influences which dominated in the carving out of the surface configuration of the Australian Alps during Pleistocene times were certainly sub-aërial; and, for the reasons assigned in this paper, it appears to me that we must concede the point sought to be established by Mr. Griffiths, in his admirable paper, "On the Evidences of a Glacial Epoch in Victoria during Post-Miocene Times"—viz., that Australia, as well as South Africa, South America, and New Zealand, participated in a glacial period.

In another article I hope to adduce further evidences of glaciation in the Mitta-Mitta sources, and also direct further attention to the question of interglacial periods; but, in concluding the present paper, have much pleasure in acknowledging the receipt of an interesting paper by Dr. von Lendenfeld, of Sydney,* in which that savant gives the results of his explorations of the Kosciusko plateau during January last, establishing the fact of the glaciation of the highest mountain in Australia, although that gentleman's inferences as to the area over and altitude at which traces of glaciation would be found to occur are somewhat at variance with the evidences herein presented. In tabulating his interesting results, the learned doctor informs us, page 9: "The climate was then not very cold, so that the glaciers only covered the highest part of the Australian Alps, and were consequently very small." If my evidences are correct, the glaciers would not only have covered the whole of the Australian Alps, but might have extended their influence to the lower levels down the Murray basin. Again, at page 4, it is stated in reference to the snow patches that—"These snow patches are never found in 'deep ravines,' as Mr. J. Stirling states.† Snow patches such as those on Kosciusko only lie close to the exposed parts where

* The Glacial Period in Australia, by R. von Lendenfeld, Ph.D.: Trans. Soc., N.S.W., Vol. X., p. 45.

† Southern Science Record: Remarks on Flora of Australian Alps.

the wind blows a greater amount of snow together, and stores it for the summer." In reply to this, I can only say that my experience during the past ten years over the greater part of the Australian Alps confirms my previous statement, that it is in the deep southern ravines at the higher elevations that the snow is most frequently found during midsummer. A splendid example of this nature occurred at Mount Hotham, and was observed by Lady Loch during the Vice-Regal visit to that portion of the Australian Alps on 15th January last. I would also remark that while Dr. von Lendenfeld is to be congratulated on the results of his scientific exploration of the Kosciusko plateaux, yet I cannot help thinking that he has done but scant justice to the writings of Professor Tate, of South Australia,* and Mr. Griffiths, of Victoria, our fellow-member.† The doctor has informed us that (page 2) the observations of Professor Tate and Mr. Griffiths "are very vague." I must certainly join issue with him on that point. It appears to me that their observations are quite the reverse of this; indeed, the writings of both these gentlemen are very clear, and their deductions from the evidences they present are very sound. Again, we are reminded that "it is up to the mountains" we are to look for glaciers, and "not down to the sea." No doubt this is correct if the area of glaciation was as circumscribed as the doctor would have us believe,‡ but from the altitude at which the evidences occur near Omeo—viz., as low as 1000 feet above sea-level—there is nothing remarkable in the statement that "erratic boulders and striated rock surfaces" should be found on the beach near Adelaide; for the refrigeration was not merely local, but general over a very large area, and oscillations of the ocean level due to cosmic causes may have played an important part in the phenomena of glaciation. I quite agree with Dr. von Lendenfeld that the date of the last glaciation was in comparatively recent times, probably later Pleistocene, and with Mr. Griffiths that the "golden washes of the latest period are in reality the products of glacial débris ground-sluiced by the ice waters." The interest appertaining to the discovery of a recent glacial epoch in Australia is, however, not alone of relative scientific value, as indicating that those

* Tate: Anniversary Address, Phil. Soc., S.A., 1878 and 1879.
† Griffiths' Evidences of a Glacial Epoch in Victoria, Roy. Soc., Vict., 1884
‡ The Glacial Period in Australia, p. 10.

cosmic or terrestrial causes which produced the glaciation of the Northern Hemisphere were alike active in the Southern; but it is of intrinsic scientific value as affording a clue to the unravelment of many highly complex biological problems relating to the distribution, evolution, and extinction of endemic organic forms.

ADDENDA.

Since the foregoing remarks were made I have, in justice to Dr. von Lendenfeld, to acknowledge the receipt of a letter from him, dated 21st inst., in which he has kindly drawn my attention to the fact that glacier-polished rocks have been photographed by Mr. Brown, Government Geologist at Adelaide, or some other gentleman, and he remarks: "I have seen the photos, and do not doubt that the rocks photographed really are glacier polished." This would confirm my previous suggestion, that the area of glaciation was very extensive. I must thank the doctor for his kindness in stating facts which would seem to be at variance with his own original deductions from an examination of the Mount Kosciusko plateaux.

Art. VI.—*On the Dynamical Equivalent of a Pressure.*

By T. Wakelin, B.A.

[Read 13th August, 1885.]

Art. VII.—*International Statistical Uniformity.*

By Henry D'Esterre Taylor.

[Read 8th August, 1885.]

In attempting to bring under notice some suggestions tending to promote uniformity in international statistics, a brief recapitulation of the circumstances which led to their inception may not be out of place. One of the vital questions which, under various aspects, is engaging public attention in the Australian colonies, is a consideration of the more prominent characteristics of the growing native (white) race, and the effects they are likely to produce on the future history of this portion of the British Empire. Perhaps the phase of this development which attracts most notice at present is the one locally known as "larrikinism," a term having a somewhat similar signification as "rough" has in London and "hoodlum" has in San Francisco. It includes all the lighter offences against order usually committed by young offenders up to twenty, or even five-and-twenty years of age. A local lecturer, who is credited with having had exceptional opportunities of forming a correct judgment, went so far lately as to assert that juvenile crime, or larrikinism, was more rampant in the colony of Victoria than in any other part of the world. Pressed for statistical or other reliable authorities, he was only able to fall back on "his own observation" in support of his statement. Doubting the correctness of his conclusions from the tenor of other statistics I had collected on the "Young Australian" question, I endeavoured to test them by procuring official figures showing the amount of juvenile crime existing, in proportion to their populations, in the principal English-speaking communities—Great Britain, Canada, and the United States—and comparing them with similar statistics from our own colony of Victoria. The results, after many hours of labour and research, only demonstrated the impossibility of succeeding in this task, owing to the dissimilarity existing in the statistical divisions adopted by each country (and more especially by individual departments in Great Britain,) in furnishing returns on precisely similar subjects.

No information of any practical use could be obtained, because no table could be constructed which would include similar figures from any two countries. In Victoria *prisoners* are classified (according to age,) in decennial periods, commencing at 20. Persons *arrested* are classified quinquennially from 10 years upwards. Therefore, under these heads 20 and 25 could be utilised as ages at which to institute a comparison. Out of ten criminal and prison returns (exclusive of industrial and reformatory schools,) hidden away amongst the contents of some 56 volumes of Lords' Papers, which had to be examined, only two possessed classifications at the age of 25, and three at the age of 20. For those who are fond of variety there is great amusement to be extracted from these returns—after you have managed to find them. The ages are classified in such a number of ways as to satisfy the most exacting. One English, one Irish, and two Scotch tables are subdivided as follows:—Under 12, 12 to 16, 16 to 21, 21 to 30, &c.; two as under 16, 16 to 18, 18 to 21, 21 to 50; one 15 to 20, 20 to 25, 25 to 30, &c.; one under 15, 15 to 24, 25 to 34; one under 20, 20 to 25, 25 to 30; one under 20, 20 to 30; two as under 16 and over 16; and, finally, one convict return is differently classified for each prison! In the United States they omit such information altogether. In a special prison report by Mr. C. H. Wines, special agent, he states that "they have no criminal statistics to be placed by the side of those of other countries." In Canada a similar state of affairs obtains, though a census of confinees under and over 16 is to be found in a special report on the prisons of that country.

While any attempt to make a reliable comparison was thus completely baffled, some general results could be roughly estimated, but could not possibly be used statistically. So far as they went, they showed that even as far as a comparison with Great Britain was concerned the statement of the lecturer was incorrect, an inference afterwards confirmed on referring to two of our most reliable authorities—Messrs. H. H. Hayter, C.M.G., Government Statist, and A. J. Agg, Esq., now Commissioner of Railways.

One great benefit which young communities anxious to gauge their progress may derive from statistics, lies in the standard of comparison they are enabled to set up on various matters affecting their welfare. In the discussion of public questions, it is often of great moment that authentic facts and figures should be published before interest in the subject of inquiry has evaporated. The importance of being able to procure readily and easily any essential information, by leading-article writers, professors, lecturers, (public or university,) and by persons engaged in the education of the masses, can hardly be over-estimated. If the foregoing allegation had been sustained, complete and correct information on the subject would have been invaluable to us as a community. It would immediately have led to a search for any exceptional circumstances which might produce such a result. The systems of education, state or private; of religious instruction, and the manner of imparting it; the method of dealing with "gutter children;" the laws applying to, and the methods of dealing with, juvenile offenders; the class of prisons they were committed to; the variety of punishments inflicted; whether whipping was resorted to, and under what restrictions; and the arrangements adopted in industrial or reformatory schools; are all questions which might have been investigated to secure the experience of other countries in which the evil could be proved to be less rampant. Practical knowledge of this description would be most useful in guiding future movement. It would supply a firm basis for legislation, and prevent merely experimental and, possibly, inefficacious action.

The disappointment arising from the result of this investigation naturally led to a consideration of the possibility of suggesting some means by which a certain amount of similarity might be secured—not entire uniformity just yet, but enough to make comparisons possible, and render them trustworthy when they were made.

Comparisons on a large scale do not require to be made continually. They are most useful when they cover a sufficiently long period to manifest the action of any new development of the laws, social conditions, resources, or discoveries in the countries they refer to; and yet not so long as to allow such progress to have been made, that the position of any one state at each period of computation should be perhaps more dissimilar than that of the various countries to be contrasted with each other.

A vast amount of the statistics annually issued have only a departmental interest, and are subdivided only to suit departmental convenience. Another large portion represent the various branches of one subject. Only the aggregate returns into which these should be condensed are required for international purposes. Another division are principally compiled for local information and use. Many annual returns (those on population, births, and deaths, for example) are estimated, and are therefore only approximately correct.

As this paper is confined to those which are requisite for international comparison only, all of those enumerated above, except the aggregate returns, may be excluded at once from consideration. Therefore, returns which supply, as far as possible, verified figures, ranged under a comprehensive nomenclature, and which are published at moderately long intervals, are most suitable to commence with, for purposes of unification. The decennial census, which is taken in all English-speaking communities, fulfils these conditions, and the suggestions contained in this paper will be confined to it. By thus restricting the consideration of the subject, and excluding all returns of a local or partial character, it is trusted that an apparently hopeless question may be brought within the range of practical effort. Any suggestions contained herein must of necessity be general in application, and point out as much the direction in which action appears to be possible, as the action itself. The first point is practicability; the second is, whether they are likely to lead up to a further development or improvement in the direction of uniformity.

As this census is now taken simultaneously throughout the British dominions, the first advance towards the desired end has been made. The last census of the United States was taken in 1880; ours was taken in 1881. If the Government of the former country could be induced to postpone the next for one year—to 1891—uniformity of date throughout the English-speaking communities of the world would be secured. If not, it is a matter worth careful consideration whether it would not be advisable to alter our date to 1890, in view of the gain likely to accrue ultimately; or, better still, for either or both Governments to accept the year which is at present adopted by the majority of nations collecting census returns. A mutual arrangement amongst two countries whose influence on the rest of the world is so powerful and so widespread would at once attract the attention of other communities. If such an announcement was made, it is probable that neighbouring nations would sooner or later adopt the same year; and it is possible that this effect might ensue before the next succeeding enumeration.

Every such accession would not only induce others to enter the combination, but also render it more difficult for them to persist in a policy which might rapidly become one of isolation. This opens a prospect of establishing unanimity amongst nations, in a comparatively short period—statistically speaking—in the foremost direction in which it has to be secured.

The next point for consideration is the form in which international statistics should be issued. Each country has its own method of compilation. In fact, in every branch of this "method" or "science" the systems of each country have (like *Topsy*) "growed," and bear little resemblance to each other. Some issue ponderous publications, apparently bound together at haphazard, where each return has no connection with the one on either side of it, but an intimate association with several others scattered promiscuously throughout the whole work. Others issue "parts" containing prepared tables, with a special report in a separate volume. In a third case blue books, arranged in sections, in which the tables and explanatory letterpress accompany each other as closely as possible, are published. These systems are all too cumbersome for our purpose. The first system may be excluded from consideration at once. No one who has ever had to examine "Lords' Papers" would ever wish to see it perpetuated in any other publication. It would simply render utterly confusing those returns which are at present simple and orderly in arrangement. In the last two considerable difficulties have to be overcome. In the first of them summary tables would have to be prepared, in which the various headings at the top and the divisions enumerated down the left-hand column would be subject to mutual agreement by the various countries entering into combination. A fatal difficulty in the way of adopting this method lies in the fact that the nomenclature to be mutually assented to would be doubled, with a corresponding decrease in any probability of agreement. To the last, or blue book, plan there are several objections. It would have to contain a small table for each subdivision, accompanied by explanatory notes. It would necessitate a very considerable alteration in almost every system of compilation at present in force. Every statist would strenuously object to the havoc it would cause amongst his pet creations. As no two countries have even similar main divisions, confusion would result, and the difficulties of comparison hardly be overcome. It would be inconvenient for the general inquirer.

In collecting his facts he would have a number of books open before him, all at different pages. Reference backwards and forwards would tend to disconcert and irritate him, would make his labour more severe, and in many cases cause his task to be abandoned in disgust. The difficulties which it is sought to remove from the path of the investigator would still exist, though perhaps in a less degree than at present.

The only way to secure uniformity would therefore appear to lie in the organisation of a scheme which will require as little agreement in nomenclature as possible, but which will practically secure uniformity by *including all statistics of international interest* which each country collects, and *no others.* The only form which can be arranged to meet these requirements is a tabulated form of summary sheet, in which each statistical authority can supply the information required from him from the statistics under his control. If each state would fill up such a form, (which, if necessary, might be printed in blank and supplied to them), and these were collected together, international statistics uniform in character would be secured. The principles on which such sheets should be compiled are as follow :—

1. That the arrangement shall be as clear as possible.

2. That they shall provide for uniformity on all necessary points, but that these points shall be restricted as much as possible, and shall leave the greatest freedom of contribution to each country.

3. That they shall not interfere in the slightest degree with the present method of compilation adopted by any statistical department.

4. That they shall include all leading information collected by any country consenting to adopt them, and therefore (*a*) that they shall provide for each country supplying statistics peculiar to itself alone, and (*b*) omitting information supplied by others, but which *it* does not possess.

5. That where, from unavoidable causes, uniformity is apparently impossible, a standard common to all shall be provided.

6. That they shall be capable of distribution in a form, which shall render them easy of access, intelligible at a glance, and instantaneously available for purposes of comparison.

First Clause.—To be thoroughly effective any such system being simply a compendium of statistical matter, collected and condensed from an immense chaos of bewildering figures, should be tabulated on as simple and straightforward a plan as possible. They should be as easy for the student to read and consult as an ordinary catalogue. They should be kept entirely separate from all other matters, and contain nothing but the mere figures on the subjects they represent. Letterpress should be rigidly excluded, otherwise authorities suffering from *cacoëthes scribendi* would rapidly multiply bewildering explanations, containing more matter than the returns themselves. If further details or explanations on any subject are required, the different official returns from which the figures appearing in these tables are extracted, can be referred to. Clearness is the first requisite in all tables of figures. These especially require it, as they are for general reference by persons who have not made figures the special study of their lives, and who do not revel in them with the ardent enthusiasm of one riding his favourite hobby. Indeed, most of those who will consult them will do so from a strong sense of duty alone. If they are to be quoted correctly, and proper deductions are to be drawn from them, (without which they will be worse than valueless), that duty must be made as easy as possible. One or two of the simpler reforms which add to their clearness may be noticed. In some returns the letters B and G, M and W, are used to denote boys and girls, men and women, respectively. The headings Male and Female, comprise each of these appellations respectively, and may always be used to express the different sexes. Again, the total column is sometimes placed on the *left hand* side, and the word "aggregate," "persons," or some similar term used. The commoner practice of placing it after the subdivisions it comprises, or at the *right hand*, should be uniformly adopted, and the word "Total" should be the only one used to express this meaning. In fact, a point carefully considered has been, as in the "Specimen Return" attached, to ascertain the most inclusive head-line, and adopt it invariably, to the exclusion of all less general or synonymous terms.

Clause 2.—To secure the advantages of the second and fourth principles, the headings at *the top of the columns* of the summary are the only ones which should be submitted for general agreement. Each heading should comprise every subdivision of its subject, and no information should appear a second time in any other place. Uniformity in this circumscribed nomenclature might be easily secured if a little pliability on the part of individuals, enforced by an expressed desire to co-operate on the part of Governments or Legislatures, should be exhibited. An effort to bring about such an agreement might eventuate in the formation of a statistical union, somewhat similar to the Postal Union, which has been so successfully established. To comprise in these summaries only those tables which are really necessary, and to have them as comprehensive as utility will permit, opens a wide door for all nations to enter through, and will remove many stumbling-blocks from the path of those who may make the attempt. In the specimen table the column at the left hand side is purposely left open. Each country can use it according to its own method of classification. The lines may contain the names of territorial or political divisions, towns, institutions, denominations or dates, as the methods of supplying the information required. They will not affect the value of the statistics. The totals at foot are what are wanted, and the detailed manner of procuring them will not matter in the least.

Clause 3.—In order to secure the co-operation which is necessary to success, it is of the greatest importance that these tables should not alter in any way the present statistical system of any country. To interfere with any such scheme, even in a slight degree, would immediately raise a storm of opposition which would at once sweep any proposed reform out of existence. They have been framed so as to coincide with and utilise existing arrangements in every way. As all care is taken to avoid unnecessary minuteness, countries whose statistics are limited in character would find little difficulty in complying with their principal requirements. Indeed, in such cases, the inclination latent in all statisticians to multiply information would be fostered and encouraged.

Clause 4, *sub-clause "B."*—If a statistical department or bureau omits to collect the information which any column is intended to contain (as the United States, for instance, appears to do under the headings " Religions of the People" and in all criminal statistics), the space has only to be left blank. When it finds that surrounding Governments are impressed with the necessity of securing authenticated intelligence upon subjects which it has hitherto neglected, it is possible, and even probable, that before long arrangements will be made to occupy the vacant ground, and so render the circle of information complete.

Sub-clause "*A.*"—To meet cases where one country possesses information too important to its own interests to be omitted, but which others cannot supply (for example, in natural products), blank columns have been provided under the spaces marked "Other ———," for them to fill up as they please, and so meet their requirements.

Where voluminous returns, infinite in particulars, are prepared, they are sure to contain the intelligence wanted for international purposes. It has only to be extracted from its accompanying cloud of figures, and to be reprinted in the form agreed upon. Neither the copiousness of the information nor the form in which it was originally issued need be altered in the slightest degree. There are few departments which could refuse to fill up a table which would contain only some of the information at their command.

We may indeed hope that by a similar process of reasoning to that in the previous case a corresponding result will be arrived at, but in the opposite direction; that tables not actually necessary would be by degrees discontinued, and that a reform which would have the effect of curtailing the too great multiplicity of statistical information, which is felt to be a growing evil, would be silently inaugurated.

Clause 5.—In many cases, and particularly in the natural productions of different countries, the variety of the information supplied makes any comparison almost impossible. The only apparent way to provide a common standard is to adopt the commonest standard of all — the standard of value. Therefore, where it is necessary, a column is provided at the end of the section in which the value of the articles enumerated may be given.* The difficulty caused by different monetary systems may be avoided by providing a second column of value. The first should contain the value in local currency; in the second the same value should be expressed in the coinage of the country to whom the returns are to be supplied. For instance, in American returns supplied to England, the first valuation would be in dollars, and the second in pounds sterling. In English returns sent to America the first column would be headed "libra" (£), and the second "dollars." The last column might be filled up by each individual country after receiving the returns, otherwise a great deal of labour would be entailed on the

* On a further examination I find the system of providing *one* column for the monetary value is in force in the summaries attached to Hayter's *Victorian Year Book.*

supplying countries in calculating values under a variety of standards. Of course, the same trouble would be entailed on receiving countries, with this difference, that they would have to turn foreign values into their own equivalents, and that if they did not want the comparison they need not make it. Great trouble in printing would also be occasioned to the supplying countries if the type set up for this column had to be constantly altered as impressions of the sheet were being struck off.

Clause 6.—Returns containing ages display the greatest lack of uniformity. They are introduced into almost all statistics, and on every subject, (even in the same country), their enumeration is different. For instance, in the Industrial and Reformatory Schools' Returns of Great Britain, there are at least *four* schemes in force for subdividing the ten years of life between the ages of 6 and 16! A close examination of the tables issued by various countries, shows that it is most usual to subdivide this information into quinquennial periods up to the age of 30, and into decennial ones afterwards. These are therefore adopted. But as local authorities, where a different classification is made use of, do not want to be hampered with this information, and as international explorers do not require any other, it is advisable that where such columns are introduced they should be distinctly separated from the rest, and arranged so that they could be recognised and picked out at a glance. They could be enclosed between *red* lines, which would signify that the columns so distinguished contained *international* amongst merely local information. Wherever most of the collected statistics fit in with the proposed summaries, but occasional matter of only local interest has to be introduced, the column containing it may be distinguished by *blue* lines, which will therefore signify that they enclose *local* figures amongst others that were of international interest. Under these suggestions, the compilation of International Statistics might proceed simultaneously with, or even as part of, the usual statistics of a country. Local arrangements might also be easily made to have them published, (with a view to easy extraction afterwards), as an additional appendix or addendum to the ordinary statistics of the nation.

The extension of these ideas to other local returns, and the formulation of other statistical signals, would be easily accomplished as the occasion arose for them. Valuable ideas would be contributed from all parts of the world as uniformity became gradually effected, and as a wish to fall in with the statistical union was manifested.

Having agreed upon the form of summaries to be issued uniformly, we have next to consider the easiest methods of securing their completion and publication. Blank sheets to any required number could be supplied to each country by one entrusted with their production; or, better still, a printer's proof could be sent, and they could print off their own supply. In addition to those necessary for their own census publications, an extra number should be struck off for binding with those of other countries in a volume to contain these only and a grand total sheet for each section. In the latter the left-hand column should contain the names of the nations contributing, and the others the totals only of the various summaries. In this form a condensed issue of uniform statistics never before attempted would be given to the world. They could be issued in volumes, which could be sold to all countries and buyers, at a price just sufficient to cover the cost of production. These books would contain at first the uniform statistics of the English-speaking communities, but eventually, we may hope, those of nearly the whole world. Once let such a publication appear, and there can be little doubt that, with each census compilation, other countries would not only contribute, but also endeavour to arange their methods of collection so as to make their contributions as complete as possible.

If it is objected that it would be impossible to secure this uniformity from British official departments, I would point to the collected and condensed statistics of Great Britain published in Thom's *Official Directory*. The same amount of labour that is expended on that publication would secure this object. If the proposed forms were once adopted that directory would naturally follow in the same direction. Arrangements might be made for the publishers of that work to collect these summaries, and supply them to those appointed to edit the statistical volume just referred to. Or they might be collected by the latter, and utilised by the former, the expense in either case being equally divided. That work, however, shows the possibility of succeeding, and in this, for reform to be possible should mean that it should be accomplished. The want of a central and permanent controlling department of statistics in Great Britain, has been forcibly pointed out in the report of the Special

Committee of the House of Lords appointed to consider the subject, and is painfully felt in this connection. As the leading country, and the one which, with her dependencies, could contribute the largest number of returns, a request from such a department would doubtless be complied with, and the issue of the summarised statistics of the world be confided to it. In formulating these suggestions I have aimed at securing simplicity above all things. In dealing with a subject of such vast dimensions as "Statistical Uniformity," the greatest danger of failure lies in attempting too much. Far better to lay a firm foundation, on which a superstructure more or less intricate may be gradually built up. The present statistical system (or want of it), is the growth of many years, and yet a late president of the Statistical Society (Mr. R. Giffen) has stated that there is still a deficiency of statistics in some directions. The basis on which this paper is laid is, that the first steps to effect its end must be as straightforward and as plain as it is possible to make them, without, at the same time, losing sight of comprehensiveness as a cardinal point; and, further, that it will take time, and *probably a long time,* to secure uniformity. I have kept fully in view that any sudden and drastic reform is quite impossible. Gradual improvement is all that can be looked for. If there is a reasonable expectation of securing uniformity under these suggestions in the same period that has been occupied in producing the present chaotic state, they would be worth further consideration and practical effort. "*Slow improvement,*" says Mr. Giffen, "*is no bar to a new system.*"

Amongst the advantages which these suggestions aim at securing in practice the following may be claimed:—They do not stop any information at present collected; they simply ask in some cases for a little more, that little being already supplied by other countries, and so fall in with, and even encourage, the natural bent of nearly all statisticians to multiply information and create statistics. In most cases the required figures (scattered, however, throughout a great variety of returns) are already supplied, and the aim is to collect them under one focus. They tread on no official corns; they offend no prejudices and upset no theories, perhaps almost as dear as life itself. On the contrary, they have been carefully devised with the intention of either falling in with or evading each of these possible difficulties. They purpose comprising everything and rejecting nothing of sufficient interest. They introduce a system of statistical signals, capable of indefinite amplification, and which may be as easily recognised by competent inquirers as the flag signals from one ship to another in mid-ocean. Instead of attempting to unify the detailed statistics of different nations, where, from unalterable causes—such as independent legislation; climate; seaboard; or the want of it; national characteristics; and natural capacities, features, and productions;—uniformity in the conditions of life is impossible, and therefore where uniformity in the information which is the collected result and the outcome of those conditions is impossible also, I have endeavoured to provide a common ground, where all may display the best they have to bring. It is like transplanting a half-grown tree, which we trust to see, as it establishes itself in new soil, spread its roots both downwards and outwards, till its wide-spreading branches eventually encircle and embrace all matter which ought to be sheltered beneath them; or, to put it in another form, I have endeavoured to lay down broad parallel lines, into which all smaller ones will gradually converge, between which they may run, and into which they will finally be absorbed.

Once adopted they should prevent, in the future, any compilation of new statistics on an independent basis. By persistently keeping their requirements under parliamentary or ministerial notice, the detail of future legislation and legislative information might be so arranged as to harmonise with their demands.

They would bring a study at present confined to a few within the range of many investigators, would enable them to make exact and accurate comparisons before suggesting reforms, and add much to our knowledge of many subjects not thoroughly understood at present. By removing Carlyle's reproach against statistics as being "dry as dust-bins without an index," they would assist not only to simplify and popularise their study, but also to attain one of the principal reforms which statists are so anxious to inaugurate and complete.

The "Specimen Return" will be found over leaf.

Specimen Summary Sheet.—AGRICULTURE AND NATURAL PRODUCTIONS.

	AGRICULTURE.																							
	Occupiers								How Occupied							Estimated value of Farm Implements, &c.	Live Stock							Estimated value
						Employées.			Stations or Runs		Farms		Gardens and Orchards		Estimated Total value		Horses and Mules	Cattle			Sheep	Swine	Poultry	
	M	F	T	Owners	Tenants	Under 20	Over 20	Total.	No.	Ac.	No.	Ac.	No.	Ac.				Milch Cows	Oxen	Other Cattle				
TOTALS ..																								

	AGRICULTURE																													VALUE	
	Farm Produce													Estimated value	Dairy Produce				Estimated value	Animal Products			Total estimated value	Other Products					Estimated value	Total Value of all Productions	
	Hay	Barley	Wheat	Oats	Rye	Potatoes	Ind. Corn	Tobacco	Hops	Rice	Sugar	Cotton	Vegetables		Milk	Butter	Cheese	Fruits		Wool	Honey	Furs		Timber						Local Currency	Foreign Coinage
	tons	bushels						lbs.							qts.	lbs.				lbs.		value.									
TOTALS ..																															

Art. VIII.—*The Cryptogamia of the Australian Alps.*

Part I.

By James Stirling, F.L.S., F.G.S.

[Read 10th September, 1885.]

The following brief notes on some Habitats of the Cryptogamic Plants of the Australian Alps are given in continuation of the author's Notes on the "Phanerogamia of the Mitta Mitta," &c., previously published in the Transactions of the Royal Society.* The value of a systematic description of the Florula of a region so unique in its geographical position with respect to any other series of mountain ranges, as the Australian Alps undoubtedly is, will no doubt prove serviceable to students of Phytography. Although we are all deeply indebted to the writings of Sir F. von Mueller, K.C.M.G., &c., our illustrious and even now venerable botanist—particularly the information given in Vol. XI. of the *Fragmenta Phytographiæ* and other publications; and also to the writings of several distinguished specialists, as Mr. Mitten,† and other bryologists, mycologists, &c.—yet, if we except the general remarks given in the local writings of Mr. Bailey, F.L.S., of Queensland, Mr. French of Melbourne, Professor Tate of South Australia, and a few other well-known Australian botanists, very little has been done towards grouping together the Cryptogamic Florula of typical areas. The altitudinal and, consequently, climatic zones of the Australian Alps, with the varying conditions of humidity and frequent alternations of geologic formations, afford excellent means of studying the differentiation of varietal forms, and, consequently, their biological developments. In a subsequent article I hope to be able to supply xylographic drawings of the micro-fungi and other lowly mycologic forms. To Baron von Mueller and Mr. Sullivan, F.L.S., of Moyston, the author tenders sincere thanks for assistance in naming the species herein recorded.

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* Trans. Royal Society Vic., Vols. XIX. and XX.

† Australian Mosses, Vol. XIX. Trans. Royal Society Vict., p. 50.

ACOTYLEDONEÆ.

Acotyledoneæ Vasculares.

1. Rhizospermæ.

1. Azolla magellianica (F. v. M.).—Is abundant in the still waters of sub-alpine pools, along the courses of the Livingstone Creek, especially near Omeo, at an elevation of 2200 feet, where its bright green, red, or purplish imbricated leaves form a carpet-like coating on the surface.

2. Lycopodineæ.

2. Lycopodium Selago (Linné).—This handsome club-moss is most abundant in the shaded crevices of granitic rocks, near the summits of Mount Kosciusko, at elevations between 6000 and 7000 feet.

2. Lycopodium clavatum (Linné).—On the gravelly depressions (old miocene river-beds) at the lower levels of the Dargo High Plains; this interesting species is found at an elevation of 4000 feet; and also near the summits of Mount Kosciusko, in similar situations to L. Selago; in the latter place in a slightly altered form.

3. Lycopodium densum (Labill.).—On the porphyritic areas near Mount Cobboras, between 3000 and 5000 feet elevation.

1. Selaginella Preissiana (Spr.)—In similar habitats to Lycopodium densum, but exhibiting great variety in the length of its stem, and in the character of its foliage, being more close and dense at the higher elevations.

2. Filices.

1. Ophioglossum vulgatum (C. Bauh.).—Common on the subalpine flats of the metamorphic schists near Omeo; 2000 to 3000 feet elevation.

2. Botrychium Lunaria (Swartz).—The common British moonwort; also occurs on the flats of the Livingstone Creek.

2. Botrychium ternatum (Swartz).—In the moist glens of Silurian rocks in the Macalister River sources at elevations of 2000 and 3000 feet.

1. Hymenophyllum Tunbridgense (Sm.).—This beautiful and delicately fronded fern is very prolific in the

heads of gullies on the littoral slopes of the Dividing Range, growing luxuriantly on decaying logs of deeply-shaded fern-tree gullies. It ascends to sub-alpine stations of 3600 feet elevation. It also occurs on some northern or inland slopes, such as the Buffalo Ranges, but it appears to be most prolific on the littoral areas where more equable temperature prevails.

1. Gleichenia circumata (Swartz).—Is more plentiful on the northern sub-alpine flats, especially towards the sources of the Benambra Creek, and in the Ovens valley. In the former it is found growing in the shade of various endemic shrubs, such as Drimys aromatica, &c., with whose dark sap, green foliage, its light emerald-tinted fronds form an agreeable contrast.

2. Gleichenia dicarpa (R. B.).—In similar habitats with G. circumata, but also at lower levels in the Mitta Mitta sources.

1. Dicksonia Billardieri (F. v. M.).—This magnificent tree-fern is the principal species clothing the heads of gullies in the Australian Alps. Its greatest luxuriance is attained at elevations of 3000 feet, where the decay of its lower fronds largely helps to form that deep vegetable mould so characteristic of these localities. A sub-alpine glen clothed with a vigorous growth of these handsome fern-trees, with tall straight-stemmed eucalyptus and acacias, and fringed with such beautiful endemic shrubs as Lomatia ilicefolia, Zeria Smithii, Senecio Bedfordii, and various asters, &c., is perhaps the most recherché of all the varied forms of botanical scenery to be met with in the sub-alpine zone of the Australian Alps.

1. Alsophila Australis (R. B.).—Also an inhabitant of the moist southern glens, but extending to the grassy slopes as well. Does not ascend to the same elevation as D. Billardieri.

1. Davallia dubia (R. B.).—Common in some localities, in the Wentworth Valley, near the Dividing Range, and in the Indi above Tom Groggin. Ascends to 3600 feet, both on Silurian and metamorphic soils.

1. Lindsaya linearis (Swartz).—On the Tambo River, especially on the quartz-mica-diorites of Mount Elizabeth. Ascends to 3000 feet.

Adiantum Æthiopicum (Linné).—The Maidenhair is, perhaps, one of the most abundant species of fern. It is found growing at almost every elevation, in rocky situations up to 6000 feet. Although most prolific in the crevices of potash-yielding rocks, as in the felsitic intrusions near Omeo, it is probable, however, that its greater luxuriance at these localities is, after all, an accidental circumstance, and that humidity of temperature predominates in causing its vigorous growth at these elevations, 2000 to 3000 feet.

1. Cheilanthes tenuifolia (Swartz).—Common on rocky situations at all elevations up to 4000 feet, particularly in granitic areas, and on the metamorphic rocks near Omeo.

1. Pteris falcata (R. B.).—In the littoral areas along the Tambo, Mitchell, and Dargo river valleys, in rich mould, of dense scrubs. Most prolific ascending to elevations of 4000 feet. Near Omeo its character approaches that of Pteris rotundifolia.

2. Pteris umbrosa (R. B.).—Ascends in some gullies from the coastal regions to an elevation of 3000 feet; generally in shaded valleys, on rich moulds, where it attains a height of three feet.

3. Pteris tremula (R. B.).—Found growing in the damp entrances to caves on the upper Silurian limestone formation, near sources of the Murray, 3000 feet elevation; also in fern-tree gullies between Wentworth and Dargo Rivers, in Silurian slate, &c., at similar elevations.

4. Pteris aquilina (Linn. var.).—Forms a dense undergrowth in the alluvial flats of some of the mountain streams, where it frequently attains a height of eight feet; it ascends to elevations of 5000 feet, and appears to be the most ubiquitous of all the endemic ferns.

5. Pteris incisa (Thunberg).—In the rich moulds of fern-tree gullies, on the littoral slopes, this bright-green species attains a great luxuriance, growing to a height of eight feet; it ascends to elevations of 4000 feet. Humidity seems to dominate the growth of this species.

1. Lomaria discolor (Willd.).—A very abundant species on the grassy heads of gullies, Dividing Range, near Omeo, where it forms a characteristic feature in the

landscape. The form of its fronds differentiates very much at sub-alpine habitats. It ascends to 5000 feet elevations.

2. Lomaria lanceolata (Spreng.).—In similar habitats with L. capensis, but confined chiefly to the fern-tree gullies on the littoral areas, &c., towards Gippsland. It ascends to 4000 feet, and at this elevation the growth is luxuriant.

Lomaria alpina (Spreng.).—This pretty little fern is very common on the metamorphic and granite areas in the Australian Alps, ascending to the Mount Kosciusko plateaux, where it is found growing in the crevices of the rocks at an elevation of 7100 feet.

Lomaria fluvialitis (Spreng.).—Not uncommon in deeply shaded gullies, near water channels, and at sources of springs on all the streams flowing from the Australian Alps; ascends to fully 5600 feet, but most luxuriant at the sub-alpine zone where moisture prevails.

Lomaria capensis (Willd.).—Is one of the most common of all the endemic ferns; generally most abundant in shaded grassy banks of creeks and gullies. On the Silurian slates, Wentworth River, at an altitude of 3000 feet, its fronds attain a length of six feet, with large pinnæ four feet long and over one inch broad.

1. Blechnum cartilagineum (Swartz).—Only observed by me on the Mitta Mitta metamorphic schists at an altitude of 2000 feet, and on the Tambo River banks at lower levels.

1. Doodia (Woodwardia) aspera (Mett.).—On the Silurian formation in shaded hill sides of Dargo and Wentworth rivers at an elevation of 2000 and 3000 feet; also on the Mitta Mitta sources.

1. Asplenium Trichomanes (Linn.).—Very abundant on the limestone rocks, in the Limestone Creek valley, at an elevation of 3000 feet, ascending in the Mitta Mitta sources on the granitic areas to 5000 feet.

2. Asplenium flabellifolium (Cav.).—All over the sub-alpine areas in the Australian Alps, not restricted to any formation, growing in rocky crevices, ascending to elevations of 6000 feet.

3. Asplenium Hookerianum (Colens.).—In similar habitats to A. Trichomanes, and at Day's Hill, near Omeo, on intrusive granite areas; ascends to 4000 feet.

4. Asplenium bulbiferum (Forst.).—Common on the moist Silurian ranges around Grant; generally in shaded gullies, on the littoral slopes; ascends to 3600 feet.

1. Aspidium acuelatum (Swartz).—Very abundant at sub-alpine altitudes on Silurian formations, especially towards the coastal regions.

2. Aspidium decompositum (Spreng.).—Occurs principally in the moist heads of gullies in the Mitchell River source basin; ascending to 3000 feet elevation.

1. Polypodium punctatum (Thun.).—On the heads of gullies in Dargo River valley, Silurian formation. This somewhat ubiquitous species is abundant; it ascends to 3000 feet.

1. Grammitis rutifolia (R. B.).—In the crevices of granite rocks all over the Mitta Mitta sources, ascending to 5000 feet; also on the Tambo and Mitchell River source basins, but most prolific on the metamorphic areas.

Acotyledoneæ Evasculares.

1. Dicraneæ.

1. Dicranella rufo-aurea (Hampe).—On the porphyritic rocks near summit of Mount Cobboras, at elevations of 5000 feet; and on the Limestone Creek at lower levels.

1. Blindia robusta (Hampe).—From the shaded sidelings of mica schist near Omeo (2000 feet) to the summits of Mount Kosciusko, on granitic rocks, at an elevation of 7000 feet.

1. Dicranum punctulatum (Hampe).—On the metamorphic schists near Omeo, between 2000 and 3500 feet.

1. Ceratodon purpureus (Bridel).—This moss is very common on the sites of old gold workings near Omeo, where the aluminous and potash soils are disintegrated; it ascends to 4000 feet.

2. Grimmicæ.

1. Grimmia apocarpa (Hed.).—Also common on the gneissose rocks near Omeo, at 2000 feet elevations. Abundant along with G. cygnicolla (C. pulvinata) and forming dense tufts.

2. Grimmia pulvinata (Hook. et Taylor).—Forms dense patches of a greenish grey on the granitic and gneissose rocks near Omeo, and at higher levels in the Mitta Mitta sources.
3. Grimmia languinosa (C. Muell.).—A form which is either this or a closely allied species, as found growing on the granite rocks near summit of Mount Kosciusko, at elevations of 7000 feet.
4. Grimmia Sullivani (C. M.).—This species was first discovered near Omeo by the gentleman whose name it bears; it is common all over the alps up to 6000 feet, principally on the metamorphic areas.

3. Tortuliæ.

1. Phascum disrumpens (C. M.).—Not common, but where found rather gregarious. Livingstone Creek, near Omeo.
1. Weisia nudiflora (C. M.).—Also uncommon, in similar localities with P. disrumpens.
1. Tortula rubra (Mitten.).—Common in the Mitta Mitta, Mitchell, and Tambo River source basins, at various elevations between 2000 and 6000 feet.
1. Encalyptra Tasmanica (Hampe)—This is perhaps the most widely distributed of all the mosses, being found at all elevations from the sub-alpine zone to the summits of the highest alps.

4. Orthotricheæ.

1. Orthotrichum laterale (Hampe).—On the banks of the Indi River, at base of Mount Kosciusko (1200 feet), and on Coowombat Creek at higher levels, principally on alluviums, at 3600 feet.
1. Apalodium lanceolatum (Mitten).—On the Moroko River and towards its sources, near Mount Wellington; upper Devonian and Silurian formations; ascends to 5000 feet.
1. Zygodon sp.—Found by Mr. Sullivan on Mount Kosciusko, when botanising with the writer during January, 1884, at an altitude of 6500 feet.

5. Funarieæ.

1. Physcomitrium subserratum (C. M.).—Previously recorded by Baron von Mueller from Dargo River,

but found by the writer on the Wentworth River sources, near main Dividing Range; Silurian formation at 3600 feet.

1. Enthostodon laxus (J. Hook. et Wils).—On the southern slopes of the great Dividing Range; not common.
2. Enthostodon minuticaulis (C. M.).—Found near Omeo, on the mica-schists and alluvium, by Mr. Sullivan during January, 1884.
3. Enthostodon apophysatus (Tayl.).—On the edge of the Omeo Plains, near Lake Omeo; 3000 feet elevation.

1. Funaria hygrometrica (Linné).—Common at the sites of burnt eucalyptus logs and on clayey soils near Omeo.
2. Funaria pulchridens (C.M.).—In similar localities with F. hygrometrica.

6. Bartramieæ.

1. Bartramia Hampei (Mitten).—On the shaded banks of the Livingstone Creek (2000 feet) and near the summits of Mount Kosciusko; metamorphic and granitic areas.

1. Philonitis appressa (J. Hook.).—On the Dividing Range, near Omeo; 4000 feet elevation.
2. Philonitis fertelis (Mitt.).—On the sources of the Mitta Mitta, ascending to Mount Hotham at 6000 feet elevation.

1. Brutelia affinis (Hook.).—On the granitic bosses of Mount Hope, between the Mitta Mitta and Hume Rivers, and also on the Buffalo Ranges, in the Ovens valley.
2. Brutelia commutata (Hampe).—Very abundant on the metamorphic schists in the Livingstone Creek valley, where it forms thick coatings in shaded sidelings; ascends to 5000 feet
3. Conostomum curvirostre (Mitt.).—Baron von Mueller records this moss from the Mienyang Mountains, but it is common on Mount Sisters, near Omeo Plains, on granitic and quartz-porphyry areas; 3000 to 4000 feet.

1. Meesia Muelleri (C. Muel.).—On the porphyritic rocks at Mount Cobboras, and also on the summits of Mount Kosciusko; the latter habitat discovered by Mr. Sullivan.

Art. IX.—*Fuller's Calculating Slide-Rule.*

By James J. Fenton.

[Read 10th September, 1885.]

Slide-rules, for use in approximate calculations, are not nearly so well known as they deserve to be; for, whilst possessing all the advantages to be derived from logarithms, they are entirely divested of their attendant technicalities. If a book of logarithms be placed in the hands of any intelligent person, unskilled in mathematics—no matter how well the method of using them, and their great advantages over the ordinary methods have been explained—it is most unlikely he will take the trouble to master them; but with the slide-rule it is very different, for, as the logarithms themselves are entirely ignored, and ordinary numbers alone are dealt with, he might, by the aid of a few simple rules, in a very short time become quite proficient in manipulating it. With the rule it is not necessary, as in the case of tabular logarithms, to look first for the numbers, then for the corresponding logarithms, adding thereto the differences for the last figure, transcribing them to paper, finding their sum or difference (as the case may be), and then reversing the process, so as to translate the result into ordinary notation. These operations, simple in themselves, often take so long that many expert calculators can (except in calculations involving the powers or roots of numbers) in most cases obtain the result in less time. In the case of the slide-rule, however, all these obstacles are avoided, and an ordinary result in multiplication, division, squares, or square-roots may be obtained at once by inspection with one or two simple movements of the scale, the mental operations of addition or subtraction being mechanically performed by the rule itself.

The logarithmic scale, in its simplest form, consists of a rule or line divided into parts proportional to the logarithms of the natural numbers from 10 to 100. Take a line of any length and assume it to be made up of 1000 equal parts; then mark off the number of such divisions corresponding to the logarithms (indices being omitted) of 20, 30, 40, &c., to 100, viz., 301, 477, 602, &c., to 1000; and place opposite to these the corresponding numbers, after which the scale may be completed by interposing in like manner the intermediate numbers, and any others in the third place that the length of scale will allow. Now, if with a pair of compasses the space spanned from the commencement of the scale to any number be simply added on to some other number, the resulting product will be found indicated at the lower leg of the compass, and similarly if the space between two numbers be measured, and an equal space be laid off from the top of the scale, the resulting quotient will be also shown at the lower point. A very few experiments with this scale, however, will exhibit one defect, viz., that the lower leg of the compass often falls altogether out of the scale; and hence the necessity of a double scale for practical utility, such as is adopted in the common *Carpenter's Slide-Rule.** In this rule, which is usually about a foot long, the results are obtained by placing scale against scale. There are, in fact, four distinct scales, marked A, B, C, and D respectively—the three former, which are alike, being double logarithmic scales, and the fourth being a single logarithmic scale exactly double the length of the others. This latter is employed for finding, in conjunction with the other scales, squares and square-roots. This slide-rule is well known, and is, I believe, much used in England amongst carpenters, mechanics, and others for rough calculations. But in this colony I have not met with a single workman who understood its use, and it is usually looked upon merely as a useful adjunct to the foot-rule for the measurement of inches.

[Another form of logarithmic rule to which reference ought to be made is the circular one, which, although not so well known as the common slide-rule, possesses many advantages over it. In the circular rule only a single scale is necessary; the slide is dispensed with, and the operations are performed by two hands or indices instead.†]

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* An interesting account of the history and use of this Rule is to be found in a pamphlet entitled "The Carpenter's Slide-Rule," published by Messrs. John Rabone and Sons, of Birmingham.

† Since the reading of this paper, I have had an opportunity of examining a most ingenious and portable form of the circular logarithmic scale under the name of the "Cercle à Calcul." In size and general appearance this instrument resembles a watch. It has two hands or indices, one fixed and the other movable, so that they may be placed in any required relation to each other; and on the two faces are engraved the scales. One of these faces is movable by means of a thumb-screw, such as is used in a keyless watch, whilst the opposite face is fixed, and may be traversed by a needle on the same pivot as, and with corresponding motions to, the needle (or movable index) on the

The rules just referred to, however, will only give results correct to two figures, and on this account they have been available only for rough approximate calculations, or merely looked upon as mathematical curiosities. To give results with even three figures one would require (reckoning twenty divisions to the inch) a straight rule 8 ft. 4 in. long, or a circular rule 1 ft. 4 in.; and to give results with four figures, one 83 ft. 4 in. or 13 ft. 3 in. respectively; and hence their inapplicability for other than approximate calculations.

This great difficulty in regard to length of scale has, however, at length been overcome by arranging the scale on a spiral. The instrument I exhibit to-night—the *Calculating Slide-Rule* of Professor George Fuller, C.E., of Queen's College, Belfast, Ireland—has a single logarithmic scale, 500 inches in length, wound in a spiral form round a cylinder barely six inches long by three inches in diameter. The old plan of placing scale against scale has been abandoned, and two indices—one fixed and the other movable—are substituted instead. This rule will give correct results to four and sometimes to five figures, and is therefore much more reliable than a table of four-figure logarithms. There is, moreover, an additional scale for finding the logarithms themselves if required, and on the inner cylinder of the slide are arranged, for ready reference, many useful mathematical tables and formulæ, including a table of natural sines.

In regard to matters of calculation generally, I may state that I have received the greatest assistance in statistical calculations from the Arithmometer, Logarithms, and Reciprocals. In the calculation of percentages, or in calculations involving a constant divisor, I consider Reciprocals* by far the most convenient and readiest of the three methods just named. The Arithmometer, I am of opinion, is still unsurpassed when exact results in over six figures are

opposite side. The movable face has three scales—viz., a scale of numbers, a scale of squares, and a scale of sines; whilst the fixed face contains a scale of cubes, and a scale for finding, in conjunction with the scale of numbers, the logarithm of a number, or *vice versa.* By means of these scales, ordinary results in multiplication and division may be obtained; the squares, cubes, square and cube roots may be found simply by inspection, and rough arithmetical and trigonometrical calculations involving such powers and roots may be readily made,—correct to the second, and often with an approximation to the third, figure. In many respects the "Cercle" is much more useful and convenient than the Carpenter's Slide-Rule; its price in France is 30 francs (about 25s.). A less portable but more useful instrument, having a greater length of scale, is also obtainable.

* A valuable work on Reciprocals is by Lieut.-Col. Oakes, A.I.A. London: C. & E. Layton, 1865.

required; also in the calculation of logarithmic or other series. But the Spiral Slide-Rule decidedly supersedes the use of all three when results involving not more than four figures are required. And when it is considered that few calculations—at all events actuarial or statistical ones—can be carried, to any purpose, beyond the fourth or fifth figure, chiefly on account of the unreliability of the data, the universal utility of this rule will be at once recognised. Take, for example, the calculation of a death-rate based on the population of a country. No one would surely imagine that the number showing the population is correct in the unit's or ten's place, and even the figures in the hundred's and thousand's place can seldom be relied on. In deducing a result of any value, it would therefore be necessary that the number of figures in the result (quotient) should not exceed the number of reliable figures in the divisor (or population); in fact, it ought to be one less.

ADDENDUM.

[Written 6th November, 1885.]

An objection often raised to the use of Slide-Rules generally is the trouble experienced (although there is no doubt that in the great majority of cases it may be done simply by inspection) in finding out where to place the decimal point in the result; but in the Spiral Slide-Rule, by a simple device, this difficulty has been overcome.

In calculating with the Spiral Slide-Rule it is advisable that the operations should be so arranged that the result may always be found at the *fixed* index. In using "constant" multipliers or divisors (as in the calculation of percentages, &c.), moreover, it will be found advantageous to set the "constant" once for all the operations in which it may be required. In the following examples of multiplication and division let C be constant:—

(1.) *Multiplication with a Constant Factor.*

$C \times d = x$, $C \times d' = x'$, $C \times d'' = x''$, &c., may be resolved into

$$\left(\frac{1}{C}\right) = \frac{d}{x} = \frac{d'}{x'} = \frac{d''}{x''} = \text{\&c.},$$

i.e. $(\log. 1 - \log. C) = \log. d - \log. x = \log. d' - \log. x' = \text{\&c.}$

(2.) *Division with a Constant Divisor.*

$\frac{d}{C} = x, \ \frac{d'}{C} = x', \ \frac{d''}{C} = x''$, &c., may be resolved into

$$\left(\frac{C}{1}\right) = \frac{d}{x} = \frac{d'}{x'} = \frac{d''}{x''} = \text{\&c.},$$

i.e. $(\log. C - \log. 1) = \log. d - \log. x = \log. d' - \log. x' =$ &c.

This resolves the operations into questions of proportion. If, therefore, in the first example, the indices be so arranged that *1* on the scale is opposite the *movable* index, and *C* opposite the *fixed* index, the ratio $\frac{1}{C}$ will be represented, logarithmetically, by the distance between the two indices; and as this ratio is the same for all the other ratios, viz., $\frac{d}{x}, \frac{d'}{x'}, \frac{d''}{x''}$, &c., it will be only necessary to bring the various values, d, d', d'', &c., to the *movable* index, and the results, viz., x, x', x'', &c., may be read off, in turn, at the *fixed* index. In like manner, in the second example, the *fixed* index is set at *1*, and the *movable* index at *C*; and then the scale is moved so as to bring the different values—d, d', d'', &c.—to the *movable* index, when the answers—x, x', x'', &c.—will be found at the *fixed* index.*

Art. X.—*Note on the Habits of Hermit Crabs.*

By A. H. S. Lucas, M.A., B.Sc.

[Read 12th November, 1885.]

A statement is constantly repeated in the text-books of zoology that the hermit crabs always protect their soft abdomens by taking up their abode in the *empty* shells of gasteropods. Thus Nicholson says: "The animal is compelled to protect the defenceless part of the body in some

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* It is stated (in a footnote) in the Instructions issued with the Rule that the two stops, which were fixed to the instruments first made, so that the beginning of the scale (100) might be brought at once to the fixed index, are now omitted as useless; but this is to be regretted, as, from the second set of examples shown above, it will be seen that such stops will prove of great advantage.

artificial manner, and this it effects by appropriating the *empty shell of some dead mollusc,* such as the common periwinkle or whelk."

Huxley (*Anat. Invertebrated Animals,* p. 340) says: "It is by means of these (claspers) that the hermit crab retains firm hold of the columella of the *empty* gasteropod shell, into which it is his habit to thrust his unprotected abdomen, and, covering over his retracted body with the enlarged chela, which takes the place of an operculum, resists all attempts at forcible extraction."

Even Van Beneden, the specialist on parasites and messmates, writes (*An. Parasites,* p. 24): "The shells which give them shelter are *such as have been shed,** which they find at the bottom of the sea, and in which they conceal their weakness and their misery."

At Portarlington I lately obtained a soldier or hermit crab (*Clibanarius barbatus,* Heller), occupying a full-grown shell of *Phasianella Tritonis,* which appeared quite fresh in its colour, and very unlike a shed and rubbed specimen, such as one does find among the rocks of the sea-bed. I placed the soldier in his shell, in a large bottle of water, in company with a living *Fasciolaria coronata* of about the same size as the pheasant shell. In about an hour the crab seemed to have inspected his companion, and to have coveted his abode, for from that time his busy claws were at work restlessly all the following evening and night, tugging at the operculum of the whelk. The bottle was in my bedroom, and I lay awake at times listening to the scuffle. In the morning the crab was found seated at his ease in the whelk's shell, while the torn fresh fragments of the foot and head of the latter were evidence in the bottle of his forcible piecemeal ejectment. It was quite clear that in this instance at least the hermit had not by any means waited until the shell it desired was empty. Nor is it likely that this is a solitary case. I believe that the pheasant shell had been acquired from a living animal. My brother, Dr. Lucas, informs me that, in a recent visit to Northern Queensland, he noted that the appearance of the tenements of the tropical hermit crabs was more often that of fresh than of dead shells.

Without denying that the hermits may content themselves with empty shells which may suit their convenience (for

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* The italics are mine.

this has often been observed), it is plain that they have also the power to take them from living occupants in certain cases. It is, I think, not a tenable hypothesis that the members of the equi-chelate genera are alone capable of such high-handed procedure. That the hermit crabs limit themselves to empty shells is a statement which, once made, has probably been handed down in the text-books, without verification, as a sort of tradition.

I may remark that the hermit crab (*Clibanarius barbatus*) which furnished this interesting observation has not been recorded before from Australia. It was described and figured by Dr. Heller as a New Zealand species in the *Voyage of the "Novara,"* 1865.* The distinguishing peculiarities are the equal chelæ, which, with the second and third pairs of legs, are densely pilose ; the long slender eyes reaching beyond the peduncles of the antennæ ; and the smooth gastric region of the carapace, rounded in front, narrowed and truncate behind.

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* Crustacea, p. 90, pl. vii., fig. 5.

THE SEDIMENTARY, METAMORPHIC, AND IGNEOUS ROCKS OF ENSAY.

BY

A. W. HOWITT, F.G.S.

CONTENTS.

Art. XI.—*The Sedimentary, Metamorphic, and Igneous Rocks of Ensay.*

By A. W. Howitt, F.G.S.

[Read November 12th, 1885.]

Section I.—Introduction.

In describing the rock formations of Swift's Creek and Noyang, I have treated of the intrusive areas which border the extensive tract of the metamorphic schists of Omeo. A Swift's Creek the intrusion of the plutonic rocks was at the very outside verge of the metamorphic schists, so that on one side the invasive igneous masses were in contact with the fine-grained mica schists of the Omeo series, and on the other with Silurian sediments, which are in places converted into varieties of hornfels. At Noyang the case is similar. The quartz-mica diorites and porphyrites of that locality are on their northern limits bounded by sedimentary rocks, which show metamorphic alterations approaching to mica schist; on the southern boundary of the intrusive rocks there are Silurian sediments converted into hornfels; so that, although the features are not so marked as at Swift's Creek, this area is clearly one of those which, as I have elsewhere pointed out, border the southern and eastern margin of the so-called regional metamorphic schists of the Omeo district.

In this paper I leave the tracts exterior to the metamorphic region, and enter upon the consideration of an area within it, wherein occurs a series of peculiar rocks, which not only differ from those which I have described as "contact schists," but which are in some respects peculiar, even when compared with the so-called "regional schists" of Omeo.

There is to be seen at the junction of the Haunted Stream with the Tambo River a part of the northern contact of the quartz-mica diorite group with the Silurian sediments. I have already elsewhere described this, and I now only refer to it as a convenient starting-point for a new departure.

In following up the Tambo River from its junction with the Haunted Stream the valley contracts between high and barren mountains, whose spurs interlock so much that it is equally difficult to travel, whether on the mountain sides, the banks of the river, or its bed. At a distance of about five miles in a direct line from the Haunted Stream the hills on the eastern side of the river suddenly become lower, their contours smoother, and the vegetation changes favourably with the change of formation. It is here that the Silurian sediments give place, on the eastern side, to intrusive and schistose rocks. At this place I observed that the schists have the character of phyllites, approaching to fine-grained silky mica schist, and not that of hornfels, as at Noyang. They resemble, therefore, the least metamorphosed examples of the Omeo schists; and I may say that here is their margin, in probably its most southern extension. The course of the Tambo River from Swift's Creek junction to this place is generally south; and it is to be observed that on the western side there are high, rough, and barren ranges of more or less metamorphosed Silurian rocks, rising steeply at a little distance from the river, which, however, flows over varieties of massive holocrystalline intrusive rocks of the quartz-diorite group. On the eastern side of the river the country is much lower than on the western side, and it is only at a distance of from seven to eight miles that it again rises into high mountains, such as Mt. Nukong or the northern peak of Mt. Elizabeth. This wide extent includes the watersheds of several streams, of which the Little River is the most considerable. Wherever I have traced up the courses of these streams I have found, with slight exceptions, as at the Little River and Watts Creek at Ensay, that they are over massive intrusive rocks. It is therefore to be noticed that in the stream-beds which show the deepest sections there are only to be seen holocrystalline rocks, while on the summits of some of the ranges there are traces of schistose and sedimentary formations.

In this part of the Tambo Valley I again find broadly those features to which I drew attention when speaking of the physical geology of Noyang. The river divides the regions of sedimentary from those of igneous rocks. Physical features such as these are found in other parts of the district, and are not confined to the Tambo River Valley.

Section II.—Analytical Examination of the Rocks.

In the area which I propose to describe in this paper there are but few sedimentary rocks in the immediate vicinity of

Ensay. Their great display is on the western side of the Tambo River, and thence to Castle Hill, which is the termination in that direction of the section accompanying this paper. They there occur in wide tracts, broken in places by the exposure through denudation of intrusive quartz diorites. The only part of the western moiety of the section which now needs any special reference is that portion which is at the western side of the Tambo, and where the Silurian sediments are well shown.

The Silurian rocks at this place are highly inclined at angles between 70° and 90° dipping to S. 20° to 30° W. This formation is continuous to Mt. Baldhead westward, and northward to the Gum Forest, which is part of the Swift's Creek intrusive area.

On descending from these hills towards the river the boundary of the invasive rocks is reached, at an elevation of about 300 feet above the stream, but the actual contact is not visible on the line of section.

I collected a number of samples of these sediments, and examined them, with following results. Speaking generally, they fall into two classes, representing the normal argillaceous and quartzose Silurian beds; but they differ from them, in so far that they have all been more or less metamorphosed.

Of the collected samples, I selected two for special examination. That which represents the argillaceous sediments is a minutely-spotted schistose rock, inclined to slaty cleavage, of a greenish-grey colour, a slightly silky lustre, and with here and there minute plates of alkali-mica, to be seen under the pocket lens in the otherwise crypto-crystalline mass of the foliations.

Under the microscope, thin slices of this rock showed that it is composed of two kinds of mica, together with granules of quartz and some black material (opacite). The spots are entirely composed of minute flakes of colourless alkali-mica, with some black material. The main mass of the rock is a mixture of the two micas, of which the second is a brown, magnesia-iron mica, which in places predominates, just as the alkali-mica does in others. The difference between the two, however, is that the brown mica occurs in the mass of the rock, and also radiates from the exterior of the spots. The quartz is in minute rounded grains. Here and there I observed colourless rod-like microliths, which must be apatite, and also rather stout colourless microliths, with oblique terminations. These have the form of tourmaline;

but I did not find them so pleochroic as I should have expected them to be.

I made a quantitative analysis of this sample, which I subjoin:—

No. 1.—PHYLLITE.

P_2O_5	·13
$Si.O_2$	56·33
$Al._2O_3$	22·94
$Fe._2O_3$	2·19
$Fe.O$	4·54
$Mn.O$	·tr.
$Ca.O$	·25
$Mg.O$	3·27
K_2O	6·10
$Na._2O$	·88
H_2O	3·87
	100·50
Hygroscopic moisture ...	·80
Sp. grav.	2·75

Allowing for the P_2O_5 and a corresponding amount of Ca.O as apatite, and for Fe_2O_3 and H_2O as hydrated iron ore, which in parts forms thin coatings in the rock, there remain the proportions of 1·877 Mol. $Si.O_2$, ·445 Mol. R_2O_3, ·293 Mol. R.O., and ·547 Mol. R_2O, which very nearly close when calculated as alkali-mica, magnesia-mica, and quartz, giving a proportion of 1·5 : 1·5 : 1, respectively ; or of mica to quartz as 3 to 1.

The second sample which I selected for examination and analysis represents the sandstones. As seen in thin slices this rock has an approach to foliation ; but this foliation also coincides with the planes of deposit. It is made up of a large number of angular grains of quartz, set in a ground-mass of smaller quartz granules, together with a few grains of triclinic felspar, and, relatively, a considerable amount of micaceous material. In this rock the quartz grains have a tendency to lie with their longer diameters parallel to the obscure foliation of the rock.

The felspar fragments are of two kinds. One is comparatively fresh in appearance, and it is compound in structure, and with low obscuration angles. The other is dull looking, is simple in structure, and has the appearance of the orthoclase found in granitic rocks.* These felspars of both kinds are original clastic grains, and not regenerated by metamorphic action. They are just such as I have frequently observed in the Silurian sandstones of the district.

The quartz grains are of different sizes, but as a rule they have all their longer directions arranged one way, and linear to each other. This arrangement I find in ordinary sandstones of the district, and is partly due to the process of bedding; but in this case it has, I think, been increased by pressure during the mechanical movements of the rocks. Moreover, some grains have been broken across in directions perpendicular to the foliation. The quartz grains vary both as to the amount and nature of their inclusions. Some are almost free from any, others have bands of fluid cavities, and again others are full, not only of fluid cavities, but also of microliths. The intersticial material representing that which at one time was mud is now wholly converted into mica, partly in scales, but also here and there in well-marked flakes. This micaceous material forms foliations separating the quartz grains.

The quartz grains of these rocks are evidently of clastic origin, but I have observed cases where secondary quartz has been added to them, so that I could with difficulty say where the original grain ceased.

The quantitative analysis of this rock was as follows:—

No. 2.—Quartzose Phyllite.

$Si.O_2$	77·50
$Al._2O_3$	13·11
$Fe._2O_3$	1·62
$Ca.O$	·82
$Mg.O$	·98
K_2O	2·32
$Na._2O$	2·64
H_2O	2·08
	101·07
Hygroscopic moisture ...	·50
Sp. grav.	2·665

* I use the word "granitic" merely as a convenient term of description, implying no more than that the rock in question has the crystalline-granular appearance of the granites, quartz-mica diorites, granitites, &c.

This analysis may be calculated, after allowing for the ferric hydrate, as being of the composition of 1·995 Mol. free quartz, ·856 Mol. magnesia-mica, and ·400 Mol. alkali-mica, which is nearly in the proportion of 5 : 2 : 1; but in this calculation the small amount of triclinic felspar is disregarded.

As I have before said, it is extremely rare to find even traces of sedimentary rocks on the eastern side of this part of the Tambo River; that is to say, which can be determined at first sight as being such. There are nowhere those tracts of alternating argillaceous and arenaceous beds tilted at high angles, and otherwise showing the familiar facies of the Silurians of North Gippsland. Those schistose rocks on the eastern side which can be determined as more or less completely metamorphosed sediments are of limited extent, are much broken and disturbed, and in places so much involved with intrusive igneous rocks, and so greatly crystallised, that it becomes extremely difficult to determine whether certain samples are to be looked upon as the completely metamorphosed sediments, or as some of the schistose varieties of the intrusive masses. Such instances I have seen on the southern crest of Contentment Hill, where they adjoin well-marked examples of the holocrystalline quartz diorites of the character I have so frequently described as occurring in this district. The schists are so much broken up, that I was not able to find any portions so indisputably *in situ* that I could ascertain their dip or strike. Their actual contact with the quartz diorites may also be partly due to faulting. Although these rocks have a general resemblance among themselves, I observed on examination that there are two varieties at least—one resembling an indurated and much and minutely contorted argillite, the other having a more pronounced schistose structure. The former variety I found, when examined in a thin slice, to be much silicified, and with the argillaceous material converted into minute scales and flakes of mica, some of which, when examined by a high power, were fibrous. In these micaceous foliations there is black granular material, much of which, but not all, is removed, together with ochreous infiltrations, by digestion of the slice in hydrochloric acid. The quartz foliations are in places peculiar, for the crystalline grains of which they are formed are so arranged as to meet in the plane between the foliations of mica in the manner in which quartz crystals can be seen to form a gangue in some lodes.

This quartz contains very numerous fluid cavities without bubbles.

This rock has been so much crushed and contorted that the foliations are in places reverted over each other.

The second variety which I examined I found to be much more complex, and to show changes approaching to the condition of a minutely-foliated gneiss. The proportion between the quartz and the other component minerals is much more equal in this than in the last-described example. The rock is foliated, and the main part consists of micaceous materials mixed with quartz grains and enclosing minute crystals, which can scarcely be anything else than orthoclase; at any rate, they are not andalusite.

There are also some minute pinite pseudomorphs after this felspar. The quartz occurs in very numerous interlocking granules, which form foliations, and also veins, branching from one to the other across the micaceous foliations.

These rocks, although still bearing much the outward appearance of sediments, prove upon microscopic examination to have been so altered as to be almost within the bounds of the group of metamorphic schists of Ensay.

The only other remaining traces of rocks which can be referred to the less altered sediments rather than to the schists are at the sources of the Watts Creek, or rather, to be more correct, a little beyond them, where the track from Ensay to Gellingall crosses a small stream before rising on to the divide which falls to the Wilkinson River. I could not find these rocks *in situ*, but only as fragments in the bed of the stream, the sides of the hills being there covered with soil. So far as I am able to judge, I think that these sediments adjoin a diabase mass on the west side, and may therefore have been subject to two separate metamorphisms—first, in common with all the sediments of the district, and second, by the diabase.

The samples in this instance represent, as elsewhere, the argillaceous and the arenaceous sediments, and I now give the results of their examination.

The first example consists mainly of a micaceous mineral, having a fibrous structure, and thus resembling sericite-mica in appearance and in its reaction with polarised light. It is colourless, or of a pale greenish tint, where not stained by iron ochre. In some of the foliations the small masses have their fibres parallel to each other, whilst in others they are twisted and lie across each other in a felted manner. In rare cases the mineral is inclined to form plates resembling an alkali-mica. In this mass there are minute crystals of what I believe to be magnetite.

The second example is more quartzose, being a mixture of a yellowish micaceous mineral in irregularly-shaped overlapping plates and scales, together with quartz grains. Some of these latter are free from cavities, while others contain them in great numbers, so that one may conclude that there are two generations of them, one being probably original, clastic grains and the other secondary and metamorphic. The rock is much stained by infiltrated iron ore.

Besides these there are fragments of rock lying on the hillside which have a remarkable amount of a soft silvery mineral in small scales and plates showing on their planes of separation. This rock was too soft and decomposed to admit of being prepared satisfactorily as a thin slice, but the examination which I could make led me to the conclusion that it is a decomposed metamorphosed sediment containing much talc in minute scales on the planes of foliation.

In the plan which I have laid down for this present work, I now return to the line of section on the western side of the Tambo River. It was more convenient to take those rocks together which could be at all considered as being within the sedimentary group, without reference to their position in or near the line of section which I am describing. But in treating of the metamorphic schists, and of the igneous rocks connected with them, this plan would not be satisfactory, for they are so intimately mixed that it would only confuse were I to attempt to select the instances of each group separately. I shall therefore now take the rocks which I noted for observation in the section as they follow each other, leaving to later on the task of summarising the respective and characteristic features of each group.

In proceeding eastwards towards the junction of the Little River and the Tambo, from the contact with the sediments on the west side of the latter river, no rocks are met with *in situ* until it is reached, where there are unmistakable examples of massive quartz-mica diorites in its bed. At the junction of the Little River there is a mass of a red-coloured crystalline granular rock, composed of reddish felspar, quartz, and some chloritised magnesia-mica. This rock is allied to the aplites, which I shall note later on as of very frequent occurrence at Ensay.

About half-way between the junction of the Little River and Tambo and the crossing of the Omeo-road over the former there is a massive, rather light-coloured rock in the bed and on the banks of the stream. It is composed of felspars, quartz, some chlorite and apatite. The chlorite is probably derived from hornblende, for I observed a portion of that mineral in one case still intact. The chlorite is of the character usual in the massive rocks of this district, markedly dichroic in shades of green, and apparently filling the place of some other mineral (hornblende) of the first consolidation. In this chlorite there is always more or less epidote, but not those minute black needles or minute rods of iron ore which here almost always accompany the chloritisation of iron magnesia-mica.

The felspars are very much altered, being filled with flakes of mica and plates of chlorite, but enough remains of them intact to show that they were triclinic. The quartz is very plentiful in rather small grains, either singly or in interlocking groups. The apatite is in unusually stout crystals, some of which have been broken across.

Part of this rock has a micro-crystalline appearance, and I found it to be largely composed of colourless epidote granules and quartz, with traces of chlorite. The mass included a few triclinic felspars. This micro-crystalline portion of the rock resembles epidosite, and is analogous to the numerous similar veins which are to be seen in the rocks at Ensay.

The main rock is a much altered quartz diorite, of a slightly different type to the massive intrusive rock of the district. It has less quartz, and was, I think, compounded with hornblende, and not with mica.

My description now brings me to those rocks which I have separated from the sediments; that is to say, to the metamorphic schists of Ensay. It might be said that some examples which I have just described as belonging to the sedimentary group should be placed among the schists—as, for instance, the phyllites of Contentment Hill. Certainly those rocks are so metamorphosed that their argillaceous components are converted into mica; but, on the other hand, they have not lost their microscopic structure to any great extent. They are but one or two stages in advance of the sediments on the western side of the Tambo, and it has seemed to me best to draw the line there, and to count all the formations which are more schistose with the metamorphic group. Indeed, the phyllites stand between the argillites and the mica schists, and pass over into each of them.

The Ensay schists are of a peculiar character, occurring nowhere, so far as my investigations have shown me, at more than perhaps a mile, or at the outside a mile and a half, distant from the junction of Watts Creek with the Little River. There are three marked varieties—quartzose-schist, pinite-schist, and gneiss—to the latter being added some examples which are, unless examined on the large scale, apparently crystalline granular. The two former represent the arenaceous and argillaceous sediments, and the latter the same in a more completely metamorphosed condition.

The first of these schists occurs on the line of section about 20 chains before reaching the crossing of the Omeo-road over the Little River, at a low cliff at the mouth of a small rill from Ramrod Flat. They are bedded, and strike about N. 45° W., being vertical in position. One set of joints traverses them, dipping N. 60° W.; and a dyke of diabase porphyrite, with accessory amphibol, scarcely distinguishable from No. 37, described at page 100, about 3 feet in width, crosses them, dipping in the same direction as the joints.

This schist is porphyritic, by reason of orthoclase nodules forming "eyes" within the foliations, and there are also irregular veins of felspar and quartz. The main mass of the bed which I selected as typical is composed mainly of pinite, which is pearly or silvery on the face of the foliations, thus resembling the lustre of the basal planes of some pinite pseudomorphs. The cross fractures of the foliations are pale olive-green in colour, with a serpentinous appearance. In places there is a good deal of brown magnesia-mica forming part of the foliations.

To obtain a correct mental picture of this schist as a whole, it would require a large number of thin slices to average the composition. The sample which I selected represented the mass fairly. Excluding the orthoclase nodules and the veins of orthoclase and quartz, I found it to be composed almost entirely of pinite material, together with numerous divergent groups of colourless talc-plates. I also observed that the felspars had been involved in the alteration, for I found a portion of orthoclase of the micro-perthite structure still remaining intact in the centre, whilst externally the alteration to pinite was complete. In addition to these constituents there is also a little magnesia-mica and its chloritic alterations, together with a considerable amount of quartz, making up the remainder of the rock.

This rock is one of the characteristic schists of the district, and in its unaltered condition must have been a gneiss rich in magnesia-mica.

A quantitative analysis of this sample gave me the following results :—

No. 3.—Metamorphic Gneiss.

P_2O_5	·10
$Si.O_2$	55·94
$Al._2O_3$	23·39
$Fe._2O_3$	·45
$Fe.O$	4·69
$Ca.O$	·81
$Mg.O$	3·58
K_2O	6·98
$Na._2O$	1·45
H_2O	3·60
	100·99
Hygroscopic moisture ...	·43
Sp. grav.	2·777

Not far up stream from this place the river-bed becomes rocky, and affords an admirable study of the formations. From this spot I made a careful examination of the successive rock-masses for some distance, both up the Little River and Watts Creek. In order to fully note and illustrate the peculiar features of these rocks, I shall now describe them with some fulness. The numbers given refer to those upon the accompanying plan, Plate I.

1.—These schists are much distorted, and contain irregular quartz foliations. The foliations of the schist appear to coincide with former planes of deposit, and strike N. 35° to 40° W. Under the microscope this rock proves to be a quartzose schist, with a little triclinic felspar, two kinds of mica, and some pinite masses. The quartz forms foliations of irregularly-shaped grains.

The felspar is also in irregularly-shaped grains, resembling fragments of crystals. They are numerously compounded, and have the appearance of albite or oligoclase, and those obscuration angles which I could measure were low, being in the zone $OP - \infty \overline{P} \infty$ from 4° to 12°. These felspars are remarkably clear and fresh.

The two kinds of mica are associated together, one being a brown dichroic magnesia-mica, and the other a colourless alkali-mica. The latter is least in amount, and the former is partly converted into a pale-coloured chlorite, which is not very dichroic. This mica shows signs of being crushed, so that the folia are in places partly separated from each other. Where it has been completely chloritised innumerable minute black needles have been formed.

These two micas and the pinite form foliations separating the compound of quartz and felspar. I defer a more extended description of the pinite until I reach that part from which I obtained those typical examples, of one of which I give a quantitative analysis.

Adjoining these schists there is a mass of crystalline granular rock, which extends to 2. It is composed of the following minerals in their order of consolidation:—

(a) Large, simple crystals of felspar, with straight obscuration, which are much worn, or cavernous in places, or even broken or crushed. *(b)* Smaller polysynthetic felspars, with more perfect crystalline forms. These seem to be oligoclase. Some of them are of less size than the others, and all of them are later in consolidation than those before-mentioned. The alteration of all the felspars is micaceous, and in all of them there is a little viridite. *(c)* Chlorite, which seems to be the alteration product of mica. It is associated with epidote. Here the whole of the mica has been converted. *(d)* Quartz in rather large grains, being the residual component.

At 2 the crystalline-granular rocks are joined by a narrow band of schist, which is followed by a vein of pegmatite, or coarse aplite, beyond which the schists again extend to 3.

I examined a sample of the narrow band of schist, and found it to be composed of triclinic felspars, mica, pinite, and other alteration products, and quartz. The felspars and quartz, as in the former schist, form foliations separated by the mica, chlorite, and pinite. As before, the obscuration angles of the felspar are low.

The pegmatite vein is very light-coloured, approaching white, and can be seen microscopically to be composed of large, irregularly-shaped felspar crystals and grains of quartz. The latter have interfered with each other in crystallising, but conform to the outlines of the former. The felspar has, in places, straight obscuration, but the crystals do not obscure homogeneously, but in different parts successively. In the basal section of these felspars I observed numerous minute wedge-shaped crystals, arranged parallel, and perpendicular to the plane of symmetry. The larger ones I could see were twinned, and in places groups of these crystals suggested the grated appearance of microcline. As inclusions, there are also a few crystals of triclinic felspar and grains of quartz. These latter have rounded sides, and have much the appearance of pre-existing crystals enclosed in the felspar.

The quartz is in large masses, and is full of minute fluid cavities massed together or in layers.

The only other constituent is a colourless alkali-mica in small amount when compared with the quartz and felspar. Rarely it occurs in the felspar itself.

The schists, which recommence at 3, and extend thence to 4, are very characteristic. In saying that they are schistose, it must not be supposed that the foliations are either wide or strongly marked. On the contrary, in all the rocks of this kind the foliations are often very narrow, and only indicated to the eye by irregular stripes, differing from each other more or less in colour. The rock thus resembles in appearance some of the schistose varieties of hornfels. These remarks apply, however, only to the foliations of the mass of the rock, which seem to represent the original planes of deposition; and I may here note that where I found these foliations most regular they had a strike near that of the normal sediments of the district. They do not apply to the foliations of quartz or of crystalline-granular texture, which are a marked feature here. The term foliation is indeed often inapplicable to these, for I have observed that they frequently run, not only with the foliations of the rock, but also across them at all angles. The quartz veins are just such as are so commonly to be seen in the Omeo district in places where there is a passage from the sediments to the schists, and I have now come to look upon them as an unfailing indication of metamorphic alterations. The veins of crystalline-granular materials are more irregular than those of quartz. They not only run with or across the foliations, but also appear as isolated masses in them. No doubt this appearance of isolation may lead to the belief that portions of the schists have suffered complete metamorphism and recrystallisation, but I am now confident that such is not a true explanation of those cases, at least, where the line of separation between them and the schists is marked. When, however, one passes into the other, as I shall show later on, at p. 79, it is different. In the cases of which I am now speaking, I believe these apparently isolated masses are connected below with other veins and masses of intrusive kind. Such veins, therefore, as a whole, form a branching network, whose meshes are filled with schists or other rocks. Veins of this kind are clearly intrusive, while the quartz veins have been deposited from solutions probably during metamorphic processes. I give in fig. 1, Plate III., a rough sketch of part of this schist-mass, showing the features I have above spoken of. At 4 there is again a sudden change to crystalline-granular rocks resembling those at 1 to 2, extending to 5, with traces here and there of a schistose structure.

Similar rocks extend to 6, where there are massive crystalline-granular rocks, with joints dipping S. 45° W. at about 80°. I found this rock to be a holocrystalline compound of felspar, quartz, chlorite, with traces of black mica. The mica is very ragged and worn in appearance, and extensively converted into chlorite, together with colourless epidote granules. It is evidently the first formed of the constituent minerals; but beyond this all that can be said is that it has the character of the black iron-magnesia micas of the quartz-mica diorites of the district.

The felspars are next in order of generation, and are of two kinds, one most probably orthoclase, the other triclinic, and of a very compound structure. The quartz, which is the latest in order of formation, is in interlocking grains, filling in and conforming to the interspaces of the other minerals. This rock therefore belongs to the quartz-mica diorites, and is part of the invasive plutonic masses.

Adjoining this massive rock there is, again, a band of schist similar to those already described. The crystalline-granular rocks again reappear at 7, with two sets of joints, one dipping S. 60° E. at about 80°, the other vertical on a strike of S. 25° W. Crossing these rocks at 8 is a dyke of micro-porphyritic basalt about 5 to 6 feet in width, dipping S. 15° W. at 70°.

I found this basalt to have a ground-mass of numerous small triclinic felspar prisms crossing each other in all directions, and thus forming a network, in the meshes of which are numerous grains of yellowish augite, together with crystals of magnetite, either singly or forming characteristic groups. In this ground-mass are porphyritic crystals of serpentinised olivine and larger ones of colourless augite.

The crystalline-granular rocks, in a much jointed condition, extend to 9. Some of them are fine-grained; some coarser, and of a red or salmon colour. They are traversed by veins of pegmatite or coarse aplite, and also by compact veins of epidosite. I examined a sample of the fine-grained variety, which I found to be a crystalline-granular compound of felspar and quartz in nearly equal amounts, together with some brown magnesia-mica. The latter was first formed, and is extremely ragged, twisted, and, in places, much chloritised. It has a little magnetite associated with it. The felspars are of two kinds, somewhat large, very much eroded, even cavernous, crystals of orthoclase, and less-wasted, or even almost well-formed, crystals of plagioclase. The quartz fills in spaces. I have no doubt that this rock is intrusive.

From 9 to 10 similar rocks extend, where then commence some contorted schists, having in one place fibrolite and quartz as a lenticular foliation. These schists cease at 11, where they are cut across by a dyke dipping S. 10° W. at about 70°. This dyke is micro-porphyritic. It has a micro-crystalline ground-mass approaching to cryptocrystalline. This is composed of minute crystals of some mineral which I cannot further determine than by saying that it may be felspar. Besides these there are some crystals of magnetite and minute grains of augite. In this mass there are numerous small porphyritic colourless crystals of augite. Frequently these crystals are broken, and their fragments separated by the ground-mass. In other places several of these crystals form groups. This rock seems to stand among the diabases, very near to diabase-porphyrite.

The schists extend to 12, but towards that spot their foliation is less well-marked. They then give place to crystalline-granular rocks like those I have described between 5 and 6, and they contain patches of much-contorted schist. The schists then recommence. In places there is an alteration of schistose and crystalline-granular structure, very suggestive of a process of recrystallisation. I have attempted to give a representation of this appearance in fig. 3 of Plate III., but I fear not successfully. The passage from one structure to the other is more gradual than I have been able to delineate. I prepared slices of part of this rock. Under the microscope I found it to have obscure traces of schistose structure in a linear arrangement of the minerals. It is composed of rounded crystals of triclinic felspars and numerous angular grains of felspar and quartz; there are also magnesia-mica, chlorite, and small masses and veins of pinite. The felspars are in preponderance. The larger number are triclinic, and of first consolidation. Many of them are extraordinarily worn and eroded.

The chlorite is pale in colour, and but slightly dichroic, and is the alteration-product of a brown magnesia-mica, portions of which are still remaining. The quartz is the residual constituent in very numerous interlocking grains.

At 14 the schists become much distorted, and have coarse, and also fine-grained, crystalline-granular veins and foliations, which in places preponderate over the schist itself. From 14 to 15 there are no rocks visible in the stream, but they reappear at 15, which is close to the ford. The rocks at this place are very siliceous, grey or greenish-grey coloured, often much contorted schists, showing minute plates of a silvery alkali-mica here and there on the foliations. They also contain crystalline-granular foliations, and small masses of red felspar, quartz, and magnesia-mica, or chlorite, and in places also plates of a silvery alkali-mica. These schists are also crossed by strings and patches of quartz.

I examined, both microscopically and chemically, a sample of a schistose rock close to 15, and of which I have given a rough sketch on Plate III., fig. 2.

The schistose part is mainly composed of angular grains of felspar, and still more angular grains of quartz, which fill in all the spaces, and interlock with each other, like a puzzle-map. Parts of the mass are occupied by pinite pseudomorphs, after some mineral of which now not even the smallest unaltered portion remains. The schistose structure of this rock is marked by the winding, yet linear, arrangement of the plates of mica (and its alteration to chlorite), and successive patches of pinite, connected by veins of the same. The felspars are of two kinds. One is simple, having the appearance of orthoclase, and a good deal altered to mica and pinite; the other is a triclinic felspar, of an appearance suggesting oligoclase, as do also its low angles of obscuration, of which I obtained several measurements.

The mica is in small, ragged-sided crystals, and, so far as one can judge from its colour, and from the pale and only slightly dichroic chlorite which results from its alteration, it is a magnesia-mica, in which that base preponderates over iron.

No. 4.—Quartz-Schist.

$Si.O_2$	74·27
$Al._2O_3$	13·14
$Fe._2O_3$	1·01
$Fe.O$	2·11
$Ca.O$	1·33
$Mg.O$	2·56
K_2O	1·49
$Na._2O$	2·91
H_2O	2·13
	100·95

Hygroscopic moisture ...	·28
Specific gravity	2·85

I have not attempted to calculate the mineral percentages in this schist. Without knowing the composition of the alteration-products in it, the results to be so obtained would be, in a great measure, hypothetical.

The coarsely crystalline part of this rock (*b* in sketch) is a crystalline-granular compound of reddish felspar, quartz, chlorite, and alkali-mica. Under the microscope I found it to be as follows:—

The felspars are mostly triclinic, with low obscuration angles. None are perfect in form, but they are broken rather than rounded off. They give evidence of force with which they have been driven against each other during the movement of the mass. The felspars are much altered to mica, some of the plates being of sufficient size to be examined under the microscope, and I found them to react in all respects like one of the alkali-micas.

Some few of these felspars are not striated, and may possibly be orthoclase.

Chlorite occurs, representing magnesia-mica, and there is an alkali-mica, both in aggregates of small scales and in larger crystals.

The quartz is filled with innumerable minute fluid cavities, without bubbles, and also with greenish microliths, in flakes, whose nature I am unable to conjecture, unless they are chlorite.

I observed, also, as showing the mechanical changes which have occurred in this rock, that several crystals of felspar had been broken across in the same line, together with the intersticial quartz between them. The fissure thus formed had then been filled by a new generation of quartz grains, forming a wedge-shaped vein. In this secondary quartz there are very numerous minute and well-formed crystals of chlorite, of the variety which has been called Helminth, from its curious resemblance to larval forms.

Some of these crystals are geniculated, and show both the basal and prismatic planes. They are not strongly dich
in shades of green to colourless.

I have mentioned the numerous crystalline-granular veins which traverse the schists at this place. I prepared a slice of one at the junction of Watts Creek. It is composed as follows:—(*a*) Felspars which are almost all triclinic and of very polysynthetic structure; none have any external planes remaining, but are broken and eroded in a great degree. Some of the felspars are much larger than others, and there are also mere fragments in the interspaces. The composition is mostly according to the Albite law, and the obscuration angles are low, being in the zone $OP — \infty \bar{P} \infty$ between 4° and 12°. (*b*) Chlorite chrystals after mica in small amount. (*c*) Quartz in considerable amount filling in all spaces.

This vein is a variety of aplite.

A second example from another vein here is, as seen in the hand specimen, a mixture of reddish felspar, quartz, and a little chlorite, with rarely plates of alkali-mica. In a thin slice I observed: (*a*) Very irregularly-shaped and broken crystals of orthoclase, which include a few rounded quartz grains; (*b*) a lesser number of triclinic felspars; (*c*) a very little chlorite after magnesia-mica; (*d*) quartz as the residual mineral. The felspars are all more or less altered to mica, and the ultimate result seems to be pinite pseudomorphs, with some alkali-mica.

This rock is also an aplite.

I now proceed to trace up the Little River for a short distance before following Watts Creek, which lies along the course of the descriptive section.

Above the ford and on the south bank of the Little River (marked 16 on the plan), there are rocks which have characters intermediate between the schists which I have described and the other more massive metamorphic rocks. They are in places crystalline-granular, and in others schistose. They are much jointed, and also traversed by veins and strings of quartz, and contain some foliation, such as these I have already described, composed of reddish felspar quartz and a little mica or chlorite. As is commonly the case in the schists at this place, pinite is plentiful in small dark olive-green to blackish-green masses, and less frequently hexagonal crystals. The sample which I examined from 16 is a light-coloured crystalline compound of felspar, mica, chlorite, quartz, and apatite, with some pinite. The felspars are better formed crystals than is usually the case in these massive schists. They are all more or less altered to pinite, small masses of which are connected by veins running between the other constituent minerals. The magnesia-mica is ragged-sided, and in places crushed, and appears to be the first formed mineral of this rock. It has been much chloritised in the manner which I have already described. Crystalline-granular epidote is associated with the chlorite, and also occurs elsewhere in small spaces between other minerals. The quartz fills in spaces as the latest formed of the constituents.

This rock is one of the massive varieties of the schists, but in this sample shows scarcely any traces of foliation.

In following up the river from this place, there are small cliffs of rock on the left-hand side which approach in character some of the crystalline-granular, and some of the schistose examples which I have now described.

At 17 the rocks are crystalline granular, but contain lenticular patches, such as I have spoken of as occurring also in the schists; one of these I observed to be composed of fibrolite and quartz.

At 18 the schists again show adjoining the crystalline-granular rocks. They are much contorted and are reticulated with veins of red felspar, quartz, and pinite, or of quartz and pinite only. It was at this spot that I collected the samples of pinite for examination and analysis. The pinite veins are between schist foliations, and thin out at each end.

The colour of this pinite is dark green to greenish black at the edges, or in thin splinters it is slightly translucent. It is massive, or with a sub-micaceous cleavage, when the mineral occurs in stout prisms. The lustre is waxy, excepting when there is an imperfect basal cleavage, when it approaches a light pinchbeck colour. Hardness 2 to 2·5. Before the blowpipe it fuses in splinters to a grey enamel. The streak and powder are greyish white. It is partly decomposed by hydrochloric acid.

I found a few individuals showing crystalline planes, and the most perfect one which I could extract from the quartz-gangue was a stout prism, about ·5 x ·25 inches across the base, with the planes

OP (001), ∞ P (·110), ∞ Pn. (hko), ∞ P ∞ (100).

These planes were imperfect and with rough surfaces, excepting the basal pinnacoid, which, as usual, had a smooth surface and a somewhat sub-metallic lustre. The prismatic angles were near 120° and 60°.

These particulars indicate that this pinite is a pseudomorph after cordierite, but I cannot feel sure that all the other examples which I extracted from this vein were alterations of the same mineral species; and still more must this be doubtful as to pinite found in the rocks, for the numerous thin slices which I have prepared of the Ensay Rocks * show that other minerals have been pinitised, notably the felspars, and most probably also magnesia-mica, very extensively.

I found this pinite, when examined under the microscope, in a thin slice parallel to the basal cleavage, to have aggregate polarisation almost uniformly throughout, but in places there were small clear portions which obscured homogeneously. Numerous cracks traverse it, along which iron ochre has been deposited. In places connected with these cracks small divergent groups of colourless talc-plates have been formed. When examined by ordinary light, and with a high power, the slice is seen to be full of microliths, there being stout, somewhat short fibres, some straight and some curved. In places these are almost "felted." In other places they are grouped together.

A slice parallel to the prism was somewhat different to the one just described. A large part of this is homogeneous, and has straight obscuration parallel and perpendicular to the basal cleavage. This mineral is colourless and very faintly dichroic, the ray vibrating parallel to the axis $\acute{c}$ being colourless, and the other (either $\breve{a}$ or $\bar{b}$) being pale yellow. The remainder of the slice shows aggregate polarisation, and iron ochre stains parts adjoining cracks. With a high power I observed the same short fibres arranged linearly parallel with the basal cleavage in those parts which have aggregate polarisation, but not in the homogeneous colourless

* I prepared seventy thin slices of the Ensay Rocks for the purposes of this paper.

parts. This sample shows clearly that the pinite of this vein has, in fact, resulted from the alteration of cordierite.

In order to gain some further insight into the composition of this pinite, and into the mode of its occurrence in this vein, I prepared a thin slice. Under the microscope this is seen to be composed of pinite individuals, quartz, and some alkali-mica. The pinite has, in some instances, when seen by polarised light, a peculiar meshed appearance, resembling that of serpentine. I have observed the same in samples of pinite from Bodenmais, in Bavaria, and Schneeberg and Aue, in Saxony. This kind of alteration proceeds evidently from the cleavages and cracks inwards. With a high power, all that I could make out, in addition to that which I have already said, was that some of the pinite is made up of minute colourless flakes, which are in places contorted and twisted together. In other places very numerous, yellowish-coloured, thornlike microliths occur in the basal sections, at all horizontal angles to each other.

The pinite individuals are evidently not all in the same state of change. In some there are still remaining portions of the unaltered cordierite, whilst others are so completely altered as to have only aggregate polarisation. In some there are included grains of quartz or plates of alkali-mica, and the latter almost always borders the pinite, and extends beyond into flaws which traverse the quartz. Magnesia-mica in chlorite pseudomorphs is only present in very small amount.

The quartz is full of fluid cavities, some of which have small bubbles.

The following is a quantitative analysis of a sample collected from this vein :—

No. 5.—Pinite.

$Si.O_2$	...	...	...	46·16
$Al._2O_3$	...	...	...	32·23
$Fe.O$	...	...	...	3·34
$Mn.O$	...	...	...	·01
$Ca.O$	...	...	...	·50
$Mg.O$	...	...	...	2·66
K_2O	...	...	...	8·75
$Na._2O$	...	...	...	·56
H_2O	...	...	...	5·08
				99·29

Hygroscopic moisture ...	1·67
Sp. grav.	2·756

Pinite is not a mineral of definite mineral composition. The numerous published analyses show this, while at the same time there is a general resemblance in the percentages given. The microscopical examination of the Ensay mineral shows that it has two varieties of structure: one which is compounded of minute scales, together with larger flakes of a colourless mica; the other somewhat resembles serpentine in its "meshed" appearance. Taking this as a basis, the following calculation may be made of the probable constituent minerals of this pinite:—

		Molicular Ratio.
Alkali-mica—	$Si.O_2$	1·252
	$Al._2O_3$	·626
	K_2O	·186
	$Na._2O$	·018
	H_2O	·422
		2·504

This leaves for the second constituent of the pinite the following:—

	Molicular Ratio.
$Si.O_2$	·325
$Fe.O$	·093
$Ca.O$	·018
$Mg.O$	·133
H_2O	·081
	·650

This calculation very nearly closes, leaving a deficiency of H_2O of ·061 Mol., and a surplus of $Si.O_2$ of ·039 Mol. If the interpretation is correct, the second mineral must be a massive talc, and the two minerals would be in the proportion of talc to alkali-mica as 1 to 3·85, or about 17 per cent. of the former, to 83 per cent. of the latter. I must, however, point out that, although the sample was collected within the space of a few inches, there was a slight perceptible difference between some of the pieces, showing that even in so short a distance there was probably some slight difference in composition. Either the colour varied in shade, or there was a difference in the completeness of the basal cleavage.

At 19 the rocks are again crystalline-granular and of two varieties. One is of finer texture than the other. The coarser-grained variety consists of felspar and quartz in nearly equal amount, with a very little brown magnesia-mica. A marked feature in this rock, as seen in a thin slice, is the angular and eroded appearance of the felspars. Some are mere remains of crystals. The larger individuals, which are also those which are most eroded, have the appearance of orthoclase. They include some small crystals of triclinic felspar. The remainder of the felspars are smaller in size, and are plagioclase. The quartz has not any peculiar features, and in appearance is like that of the intrusive rocks of the district.

The finer-grained variety, which is much intermixed with the coarser, is a micro-crystalline granular compound of felspar and quartz, with a good deal of brown mica in scattered flakes. The felspars are all in angular fragments, and, to judge from their structure and from their low obscuration angles, one of the more acid of the soda-lime group. They are very clear and unaltered. Besides these, there are other and larger porphyritic crystals, less numerously compounded than the others, being either Carlsbad twins, or else this combined with a few lamellæ according to the Pericline law.

This rock is traversed by very fine-grained light-coloured veins. I have before said that such veins are commonly to be seen in the Ensay Rocks, more especially the intrusive ones. This sample is composed almost wholly of almost colourless epidote in characteristic crystals, and also in masses of crystalline grains, the remainder of the mass being made up of quartz. The larger epidote crystals are in the centre of the vein, and the granular mixture of quartz and epidote is at the sides. Isolated epidote crystals occur in the rock bounding the vein.

These crystalline-granular rocks extend to 21, where is a binary compound of felspar and quartz, which at 20 contains portions of contorted schists, together with patches of coarser materials, such as I have described before.

Beyond this place the rocks to be seen in tracing the Little River up to the contact of the intrusive massive rock, which is near the Ensay homestead, are schists. Some have a massive character, while others are like much-altered phyllites. In order to learn something of the character of these schists, I prepared slices both of the schistose and the massive types.

Here, as elsewhere, two kinds of schist can be distinguished, one representing the arenaceous and the other the argillaceous sediments. I found a sample of the former to be composed of irregular foliations of quartz and felspar, mica and pinite. The micaceous foliations are comparatively narrow, and are in places mere partings. The quartzose foliations are made up of grains of quartz, which are in most cases, as seen in the thin slice, much longer than wide. As these grains can be seen in the slice to overlap, it is evident that they represent small discoidal or lenticular masses lying with their flat sides parallel to the foliations. Some of the quartz foliations bifurcate and again combine, enclosing micaceous portions.

The quartz is full of minute fluid cavities, some of which contain bubbles. Of inclusions there are few, and these are oval colourless to brown microliths and colourless minute rods or prisms, which are probably apatite.

The felspar grains are few in number, and as they are unstriated I consider them to be orthoclase, which in other respects they resemble. They are kaolinised and contain minute flakes of viridite. These felspar grains only occur in the quartz foliations.

The micaceous foliations are narrow, but in places widen out to "bulges," and include grains of quartz. Under a high objective the mica is seen to be of a light-brown colour and to be pleochroic. Much of this mica is chloritised.

The argillaceous variety I found to be composed of alternating foliations of quartz and of mica. This mica is partly in scales and partly in ragged fibrous flakes. There is also some chlorite.

The quartz grains are angular, and are arranged in a linear manner, thus forming foliations. They contain very numerous fluid cavities, with bubbles, and in parts many colourless minute prisms or needles of apatite, which throughout the slice all lie in, approximately, the same direction, parallel to the foliations.

This rock resembles the last described, but the proportion between the quartzose and micaceous materials is reversed. The magnesia-mica in this rock has also a distinctly fibrous structure, and is associated also with alkali-mica, which I did not observe in the other. In places the mica and quartz form a confused aggregate, and not foliations.

These rocks, it seems to me, have been completely recrystallised, for I am unable to satisfy myself that any of the quartz grains are of clastic origin; yet I can feel no doubt, after the extended examination which I have now made of the Ensay Rocks, that these schists were once sediments.

These two examples are from 22, and represent the schistose types. It yet remains to examine the massive variety. For this purpose I prepared slices of two samples—one collected at 23, and the other at 24.

The former is a compound of angular grains of quartz, brown mica, and micaceous alteration-products, in about equal amounts. I cannot say what the micaceous aggregates may represent, unless felspars, of which there is no trace in the slice. The mica is brown and pleochroic, and it is partly converted into a rather pale and not very dichroic chlorite, with the elimination of iron, in needle-like crystals. When examined by a high objective I find that the micaceous aggregates are full of minute stout, straight, or curved microliths. I might call them stout fibres, similar to those which I have spoken of finding in the pinite. In places these are arranged linearly, or in linear groups, so that they produce a fibrous effect.

The quartz grains are of two kinds—one which contains very numerous colourless hair-like microliths, the other without them. Where the microliths are absent there seem to be many more fluid cavities. This may, perhaps, indicate two generations of quartz grains.

The second sample is from the massive bedded schists at 24. Under the microscope it is seen to be composed of small masses, having aggregate polarisation, such as occur also in the last-described rock. There are also spaces filled by pinite; and a rudely foliated structure is produced by the association together of these with a little brown magnesia-mica, colourless alkali-mica, and divergent fan-shaped tufts of talc.

The quartz grains are numerous, and generally scattered irregularly in the mass, but also more or less lying between the foliations.

There are no felspars to be seen in this sample, but it may be that they have been wholly converted into the micaceous aggregates of the foliations.

At the spot marked 25 upon the plan there is a strong dyke having a meridianal strike. It probably extends much further to the north, for there is an outcrop of a similar but somewhat altered dyke close to the Ensay homestead, and, as it seems to me, in the line of strike of this one. To the southward, also, there is another dyke of the same kind close to the Omeo-road. These three occurrences, I suspect, are either of one and the same dyke or of separate dykes in the same strike.

The dyke-stone is greenish-grey in colour, with a compact ground-mass with porphyritic long-bladed crystals of hornblende, which are now much chloritised. In places there are also hexagonal crystals of chlorite after magnesia-mica.

Under the microscope this rock has a ground-mass containing a little yellowish-coloured basis, but the greater part is a micro-crystalline aggregate of felspar and quartz in grains. Throughout this ground-mass there is a good deal of chlorite in minute flakes and fibres. The ground-mass contains—(*a*) Rather large rectangular crystals of titanic iron, which all show more or less alteration to Leucoxen. Some of these crystals are what I can only describe as skeleton crystals, having partly-formed bounding planes, including ground-mass. (2) Eroded quartz crystals, which include magma. (3) Long-bladed, light-coloured crystals of amphibol, with broken terminations. They are pleochroic in shades of green. Intergrown with this amphibol, but on only a small scale, is a fibrous rhombic pyroxene, which is dichroic in shades of brown.

The alteration of the amphibol is to chlorite. The felspars are altered to a great extent to granular materials, which, together with flakes of viridite, make up most of their substance; but traces remain of their former structure, which show that they were triclinic. This rock is therefore a variety of quartz-diorite.

I now return to the junction of Watts Creek and the Little River, in order to complete the description of the rocks seen in tracing up the former stream in the line of the general section.

From the junction of Watts Creek to the spot marked 26 there are continuous outcrops of schistose and igneous rocks, intermixed more or less. The latter are mostly as veins, with the characters of aplite. At 26 there is a mass of schists with numerous foliations of quartz and small masses or irregular veins of mixed felspar and quartz, up to 6 inches in width. The schists resemble those which I have mentioned, and described at 1, but are more altered.

At 27 occurs another patch of much-contorted and winding vertical schists, but having perhaps an average strike to N.

20° W. These schists also resemble those at 1, but have suffered more alteration in so far that in places the schistose structure is almost obliterated in the finely crystalline-granular mass, with quartz foliations, quartz veins, and veins of felspar and quartz traversing it.

I found a thin slice, which I prepared from one of the most altered of the foliations in which the schistose structure was not quite lost, to be composed of innumerable grains of quartz fitting into each other and into the other minerals like a puzzle-map. Among the quartz grains some are much longer in the direction of the foliated structure than in the other, and in some of these I observed to be included small rounded grains of quartz. It has suggested itself to me that in these included grains one may perhaps recognise the remains of the former clastic quartz grains of the sediments, and in the larger ones surrounding them secondary quartz, deposited during the metamorphic processes. This view would require that the original quartz of the sediments should, under such conditions, have been dissolved and re-deposited. I shall later on return to this question, when considering the principal and characteristic features of the Ensay Rocks, which I am now describing in detail.

The mainly siliceous mass of this rock is rudely parted into foliations by irregular masses and connecting veins of pinite, with a little brownish magnesia-mica, and its resulting alteration to chlorite, which, as in other cases, has eliminated ores of iron, to be re-deposited in the basal section of the chlorite in the form of minute opaque black needles, crossing each other approximately at angles of 60° and 120°.

There are also felspars, as angular grains, some of which are orthoclase and others plagioclase. The former are much altered, and in places completely, to pinite. The latter are comparatively fresh, the only change which I observed being the production of flakes of mica along cracks and cleavage planes. These triclinic felspars are very compound, according to the Albite law, and their low obscuration angles suggest albite or oligoclase.

At 28 occurs another outcrop of schists which have some interesting features. Taken as a whole they are not siliceous, but belong in great part to that section of the group which I have spoken of before as pinite schist.

The schists are very much contorted, and are penetrated by veins of felspar and quartz, and also of crystalline-granular materials.

The strike of the schists is probably about N. 10° W., and the veins are intrusive.

I prepared examples of the two varieties of this schist, one siliceous and the other pinite. The former is grey in colour, with a tinge of olive-green. In the hand specimen one can see that the quartzose foliations are separated by narrow partings of basic materials. Under the microscope I observed it to be a schistose compound of quartz, felspars, two kinds of mica, pinite, and chlorite. The felspars are in angular grains, and are all triclinic, with low obscuration angles. The measurements which I made in the zone $OP - \infty \bar{P} \infty$ were between 1° 30′ and 11° 30′. The micas are magnesia and alkali micas, which in many cases are associated together. The former is much chloritised, but where intact the dichroism is not strong. The pinite occurs in irregularly-shaped masses. The quartz grains are such as I have before described in these schists, and make up by far the larger part of the rock.

The second variety examined is a pinite schist with quartz grains.

The pinite forms foliations separated more or less by irregular continuous partings of magnesia-mica with some alkali-mica. The pinite has the same appearance under the microscope which I have already described, but a few additional remarks may be made with advantage. In slices parallel to the foliations it has aggregate polarisation, and in places also a "meshed" structure, resembling that of serpentine. No unaltered parts of any original mineral remain, but in place there are what seem to be pseudomorphs after cordierite. When examined by ordinary light, and with a power of about 55 linear, such individuals are seen to be made up principally of minute bent and twisted flakes, which, as seen edgeways, have the appearance of fibres. The larger ones react like an alkali-mica.

In a slice across the foliations the pinite had a much more serpentinous appearance, the meshed structure being more marked.

The magnesia-mica is brown in tint, and not very pleochroic. It is very much intergrown with alkali-mica, not only by alternations, but also by the juxtaposition of the two micas. The quartz is in isolated rounded grains, almost in all cases in the micaceous foliations, and but rarely in the pinite.

In one slice I observed a patch of a colourless or grey fibrous mass. The fibres formed long-bladed crystals; or it might be said that the fibres were in bundles, and these lay across each other at acute angles, thus forming an approach to a radial aggregate. It has straight obscuration, and very much resembles pyrophyllite. Talc also occurs in divergent scales.

A little higher up the creek, at 29, there is another outcrop of similar schists, of which I examined the pinite variety both optically and chemically.

As seen in a hand specimen, the foliations have in them numerous small silvery scales, which yield to the nail, and have the appearance of talc. On a cross fracture the rock has a greenish tint, and at the edges is slightly translucent. The hardness of the rock is from 2· to 3·.

Under the microscope it proves to be a confused mixture of pinite material, magnesia-mica, alkali-mica, talc, and grains of quartz. The pinite does not differ from that just described. The magnesia-mica is here and there intergrown with alkali-mica, and is much altered to a pale-coloured chlorite. The quartz is in isolated rounded grains.

Subjoined is the quantitative analysis of this sample :—

No. 6.—Pinite Schist.

P_2O_5	·tr.
$Si.O_2$	45·72
$Al._2O_3$	24·31
$Fe._2O_3$	4·72
$Fe.O$	7·32
$Ca.O$	·61
$Mg.O$	4·27
K_2O	6·47
$Na._2O$	·77
H_2O	5·83
	100·02

Hygroscopic moisture ...	1·33
Sp. grav.	2·78

Without some more definite knowledge as to the constitution of the different minerals in this schist, it would be merely haphazard to attempt to calculate the percentages.

The analysis shows a marked resemblance to that of the pinite given at p. 85; and perhaps this much may be ventured upon, that the main part of the rock is composed of pinite. In this view, I have applied the name Pinite-schist to it.

From here the rocks seen in following up Watts Creek are less schistose, and more crystalline-granular. Of the former, some are so massive that it is only when looking at them *in situ* that their schistose character becomes evident, the hand specimens seeming to be crystalline-granular or porphyritic. Some schists have the structure of "Augengneiss."

I collected samples of the typical rocks which I observed at the place indicated, as before, in the map by numbers, up to the place at which undoubted invasive rocks appear—that is to say, where it is possible to place the contact boundary of the Ensay schists.

30.—There is here a mass of pale, flesh-coloured crystalline-granular rock, composed of reddish felspar and quartz, with very rare plates of alkali-mica. Under the microscope I determined it to have the following composition:—(*a*) Felspars. The most prominent felspar is orthoclase in much-wasted and eroded crystals, which obscured successively in different parts after the manner of the potassa felspars of some pegmatites. The second felspar is triclinic in crystals, compounded according to the Albite law. These are also very cavernous. The angles of obscuration which I could measure in the zone $OP — \infty \bar{P} \infty$ were low, being between 1° and 14°, and in a section approximately near $\infty \breve{P} \infty$ 19° 30′. This felspar seems, from these observations, to be oligoclase.

There is a very little chlorite and a few flakes of alkali-mica, and the remainder of the rock is made up of quartz granules.

This rock is an aplite, and, according to its appearance *in situ*, would have been formerly described as Eurite.

I also examined a similar rock near at hand. It resembled the one just described, with this exception, that it contained a rather larger amount of chlorite after mica, and that some of the felspars were pinitised.

In both examples the felspars, as also the residual quartz, contained small quartz grains.

The marked feature of these rocks, as also of others of the same class at Ensay, is the wasted and cavernous condition of the felspars.

31.—A massive, rather fine-grained, aplite occurs here. It is composed of reddish felspar, quartz, and a little magnesia-mica. It is traversed by east and west joints. Following it, and continuing up to 32, are coarsely foliated schists, with pinite. The partings of these rocks strike N. 20° W., and in places the schistose structure is very evident.

At 33 there is an outcrop of rocks which, it seemed to me, fairly represent the most completely metamorphosed schists in this part of Watts Creek, in which not only the sedimentary but also the more foliated schistose structure has been obliterated.

I found it to be composed of large felspars, mica, and quartz. The felspars are of two varieties. One is in large, ill-formed crystals, or, more properly, crystalline masses, in which the obscuration indicated orthoclase. One instance had veinlets of a second felspar included in it, as is the case with orthoclase perthites. These felspars are not uniformly altered, being in places kaolinised, and in others converted more or less into pinite and mica.

The other felspar is in smaller and more perfectly developed crystals. It is very compound, and the obscuration angles which I could measure I found to be in the zone $OP - \infty \bar{P} \infty$ between 1° 45′ and 16° 30′, suggestive of oligoclase.

The magnesia-mica is almost wholly chloritised, and it is associated with rounded, or nearly rectangular, pinite pseudomorphs. Alkali-mica is also present, accompanying the pinite.

The quartz is residual, filling in spaces, in rather large interlocking grains.

The microscopic examination of this rock shows that its features are those rather of the massive schists than of the intrusive rocks. The orthoclase felspars resemble those of the pegmatite contact veins; the magnesia-mica is poorer in iron than that of the intrusive rocks which I have examined, and the pinite pseudomorphs are just such as those I have already described.

Rocks which are somewhat more distinctly schistose extend to 34 on a strike north, where they again become more massive, and adjoin aplites.

These massive schists are in places porphyritic by reason of small masses of felspar and quartz, or of one or other, which form the centres of bulges in the schist foliations. In other respects a sample of this rock, when examined under the microscope, did not differ materially from that which I have just described.

35.—At this place the rocks are distinctly crystalline-granular, having a "granitic" appearance. They are traversed by winding veins of a reddish-coloured aplite, and by narrow veins of epidosite.

I examined samples of these two rocks. A slice of one of the most "granitic" samples I found to be a holocrystalline rock, formed of triclinic felspars, quartz, and chlorite. The last-named mineral is in large, ragged masses, of precisely the character of the chlorite after the Haughtonite mica of Noyang. The original mica is now all converted, but I can feel no doubt that it was the first-formed mineral after magnetite. The felspars came next in order of consolidation. They are in very compound crystals, with higher obscuration angles than any which I have had to record yet in this paper. I made measurements in the zone $OP — \infty \bar{P} \infty$, between 3° 30′ and 30° 30′, and in one section which was near the plane $\infty \breve{P} \infty$, the angle was as high as 40°. In this section, which was otherwise simple, there were a few short twin lamellæ interposed in one corner, not precisely in accordance with the Pericline law.

The quartz was last formed, and differed in no respect from that of the quartz-mica diorites of the district. A slice from a second sample from this place shows a well-marked crystalline-granular compound of felspar, with much dark-coloured hornblende and chlorite and some quartz. The first-formed constituent is hornblende, in very much wasted and cavernous crystals, which are in all cases more or less chloritised or replaced by crystalline masses of epidote. The felspars followed next in order of consolidation, mostly triclinic, but with a very few individuals of orthoclase. The triclinic felspars are not well bounded by crystalline planes, but are very compound, according to the Albite law, and also in some instances again after the Carlsbad and Pericline laws. The obscuration measurements were not satisfactory, but two in the zone $OP — \infty \bar{P} \infty$ were 13° 30′ and 30° respectively. The triclinic felspars in these rocks seem to be of the Labradorite group.

These rocks are clearly quartz-mica diorites, and also the first of what I may call the normal intrusive rocks of the district, which I have had to describe in following this section from Ensay.

The aplite veins which traverse these rocks are reddish in colour, and rather compact in appearance, showing in places a little grey-coloured quartz. They are themselves traversed by very small veins, almost mere partings of epidosite.

The felspar of the sample which I examined is mainly orthoclase, in large irregularly-formed masses rather than crystals, including quartz grains. This felspar is orthoclase. A second felspar is in few small and broken crystals, many of which are much wasted. There is a very little magnesia-iron mica, and the remainder of the rock is made up of quartz grains.

I made a quantitative analysis of this rock for comparison.

No. 7.—Aplite.

$Si.O_2$	75·74
$Al._2O_3$	12·45
$Fe._2O_3$	1·02
$Ca.O$	1·00
$Mg.O$	·08
$K_2.O$	6·77
$Na_2.O$	2·91
$H_2.O$	·33
	100·30

Hygroscopic moisture ... .47
Sp. grav. ... ... 2·635

In calculating the mineral percentages of this rock, I have kept in view the small amounts of epidote unavoidably included in the sample, the traces of magnesia-mica, and the hydrated iron ore which colours the rock. Allowing for these, there remain only constituents of the felspars, the surplus $Si.O_2$ representing free quartz.

On this basis a calculation is practicable which gives a result of felspar to quartz as ... ... 2· to 1·

Or, Orthoclase	41·80
Albite	25·72
Quartz	32·48
	100·00

In this are disregarded the amount of about 4 per cent. of the rock, which is composed of epidote, magnesia-mica, and ferric-hydrate.

At this place there is a strong diabase dyke which crosses the creek bed. The rock is much altered, most of the ground-mass being serpentinised, and in the remainder chlorite has been produced together with very numerous minute colourless rounded grains with rough surfaces, which are doubly refracting, and which I think are epidote. The marked features of this rock, as seen in a thin slice, are the amount of unaltered augite in colourless or slightly reddish stout crystals, and also the paucity of felspars. The augite obscures up to angles of 36°.

36.—At this place there appears a typical example of the massive intrusive rocks of the district, and it is here that, I think, must be placed the approximate contact boundary between them and the metamorphic schists.

For the purpose of comparison, I have made a quantitative analysis of this rock, as well as examined it in a thin slice. Under the microscope I find that it consists of the following minerals, noted in their order of consolidation:—Amphibol is in cavernous crystals, which are pleochroic in shades of yellow to dark-green, the several rays being—c, dark green; > b, dull green; > a, yellow. The angle c : C I found in a section near to $\infty \grave{P} \infty$ to be 26° 45′, and in a second, 29°. These angles are very high, but the characteristic prismatic cleavage of very nearly 124° 30′, and the strong pleochroism of the mineral, leaves no doubt as to its being amphibol. Mica is in ragged and crushed crystals, which in the slice become translucent in dark shades of yellow; macroscopically, they are black and shining. It is dichroic in shades of yellow to nearly black, and in places is intergrown with the amphibol. There are traces of chloritisation of this mica, which commence at the outside and follow the plates unequally. This mica contrasts with that of the schists by its large percentage of iron, which is evidenced by its more marked pleochroism; also by that of its resulting chlorite. It is probably, as is that of the Noyang quartz-mica diorites, a Haughtonite.

The felspars are all triclinic. There may have been two generations, if it is possible to draw such an inference from the observation that some felspars are very much broken and worn away at the sides, while others are tolerably well developed and intact. I obtained some fairly satisfactory measurements of the obscuration angles. Taking those which were in the zone $OP - \infty\bar{P}\infty$, I had measurements of 8° 30′, 14°, 18°, 20°, and 30°, and there were four sections which were approximately in accordance with $\infty\breve{P}\infty$, in which the measurements were 14° 45′, 15°, 16°, and 19°, but two other similar sections gave me angles of 28° and 35°. respectively. These angles cannot well indicate a felspar more acid than a Labradorite. The crystals are compounded, some after the Albite law, some after both it and the Carlsbad law. In some individuals zonal growth is well shown. The alteration of all these felspars is micaceous.

Quartz is in considerable amount, and of the usual character of that found in the massive holocrystalline quartz diorites.

The subjoined is a quantitative analysis of this rock :—

No. 8.—Quartz-Mica Diorite.

$Ti.O_2$	·tr.
P_2O_5	·tr.
$Si.O_2$	62·43
$Al._2O_3$	17·88
$Fe._2O_3$	1·78
$Fe.O$	3·53
$Ca.O$	3·43
$Mg.O$	4·50
K_2O	2·75
$Na._2O$	3·10
H_2O	1·37
	100·77

Hygroscopic moisture ...	·315
Sp. grav.	2·74

At this place the schists, which have been the special objects of this paper, cease. That is to say, there are from here onwards up the course of Watts Creek only here and there traces of schistose rocks, the whole tract being occupied with massive intrusive rocks. Of these I shall note a few examples as illustrating this part of the section, before proceeding to briefly note some rocks which occur in the latter part before it terminates on the eastern side of the Tambarra River.

In the upper part of Watts Creek there are numerous examples of intrusive dykes. Some are quartz porphyrites, others are basic dykes, which can only be distinguished from each other by means of microscopic examination. One such, which in appearance would formerly have been classed as Aphanite, I found to be a Diabase porphyrite, having a ground-mass of light-brown basis, and exceedingly numerous minute lathlike felspars. In this are short and isolated stout prismatic crystals or groups of crystals of an almost colourless augite, and a few large serpentine pseudomorphs, which may havé been olivine, but which have not the marked rhombic outlines so frequently found with this mineral.

37.—This sample is taken from a mass of rock which fills up the whole bed of Watts Creek, at a distance of about half a mile from 36. It is composed of orthoclase, a little plagioclase, some chlorite and quartz, and a considerable amount of pinite material, with its usually associated alkali-mica. The felspars have been, as in many of the Ensay Rocks, considerably broken and crushed. I feel myself unable to determine whether this is a completely metamorphosed schist or an intrusive rock. Judging from its appearance *in situ* I incline to the latter belief.

Near this place there is a pegmatite vein composed of cleavable masses of yellowish felspar, glassy-looking quartz, and silvery alkali-mica; in fact, a typical example of a very common class of veins, which occur in the Omeo district in connection with the metamorphic schists, and less frequently in other parts of the mountains where there are contact schists of the hornfels type.

The felspar in this vein is in cleavable masses up to three inches in diameter. and I collected an example of it for both microscopic and chemical analysis.

I prepared several thin slices in three directions, from pieces struck from the most marked cleavage (OP), from others from the less perfect cleavage $\infty \breve{P} \infty$, and thirdly from slices as nearly perpendicular to those two directions as I could prepare them.

Sections prepared from the most perfect cleavage show a main felspar mass, which is, however, not homogeneous throughout. It becomes obscured in different parts as the slice is slowly rotated between the crossed nicols; but these areas are not sharply defined, but it is rather that the obscuration passes like a cloud from one part to the other. The limits of this variation in the obscuration angle I found to be about 2° 30′; for observations varied in different parts of the slice from 6° to 8° 30′ as referred to the trace of the second cleavage.

Numerous veinlets of a second felspar traverse the main mass approximately at right angles to the above-mentioned cleavage, and thus may be considered to agree in position with the macroaxis. This is further shown by their extreme irregularity in width, being in parts mere threads, and in others bulging out into small masses. Some veins bifurcate and others run out. This irregularity of structure is, I think, connected with the difficult separation of the felspar in the direction of the macropinnacoid. This second felspar is sharply twinned parallel to the edge $OP - \infty \breve{P} \infty$, and obscures on either side of that direction at angles, as measured in different parts of different slices from the same sample, of from 30′ to 3°.

I have attempted to show the structure of the felspars as I have now described it in fig. 4, Plate IV.

In the slices prepared from pieces of the second cleavage I found the same two felspars. The main mass obscured in the same partial manner as in the basal sections at angles which differed by 2°. These observations, as referred to traces of the basal cleavage, were from 6° 30′ to 8° 30′. Traversing the main mass there are veinlets of the second felspar, which are here also very irregular, both in width and extent, as will be seen from the sketch given in fig. 5, Plate II. As referred to the traces of the basal cleavage in the slice, the inclination of these veinlets was 63° from the direction of the axis c. These veinlets, therefore, follow the direction of the macropinnacoid, and, as I have said, their extreme irregularity conforms with the obscure cleavage in that direction. This second felspar obscured in different parts of the same slice at from 15° to 18°, as referred to the trace of the basal cleavage.

In one slice I observed some fine lines of a felspar which obscured at a position of the slice different to that of either of the others. I did not find it practicable to measure its obscuration angle, owing to the extreme thinness of the lamellæ. It may be, however, conjectured as being oligoclase, to which also the small percentage of Ca.O. in the analysis points.

The slices cut perpendicular to the planes OP and $\infty \breve{P} \infty$ showed, as might be forecast, features in conformity with the structure I have described. The main felspar obscured at angles as referred to the trace of the less perfect cleavage of 6° 30′ to 9°, thus agreeing fairly with the other observations, taking into the consideration that the slices were not precisely true to the intended direction. The second felspar showed in these slices in much larger amount than in those of either of the other directions, no doubt, owing to the slight angle which the slice formed with the veinlets. It is sharply twinned in very numerous lamellæ, the obscuration angles of which are from 10° to 14° on either side of the composition face.

In addition to this form of twinning, according to the Albite law, I also observed a number of twinned crystals, seldom compounded of more than two members, which were interposed according to the Pericline law. These crystals occurred singly or several near to each other, and their terminal planes were sharply marked, while the others were usually irregularly bounded by the walls of the veins themselves.

The only other inclusions which I observed in this felspar were a few small quartz grains, and several small divergent masses of talc plates. This felspar is entirely in accordance, in its characters, with the felspars which I have collected and examined from similar veins at Omeo, and in other parts of the district.

The main felspar does not obscure in the basal section parallel to the edge P.M. It is therefore not monoclinic; and this is also further shown by the inclination which I find the cleavage faces always have to each other. It has not the extinction angle usually given for microcline; but I have observed that in felspars such as this the angle is not a constant one, and I therefore class with microcline all those potassa felspars which are triclinic in form, although their obscuration angles may, as in this case, be less than 15° 30′. The second felspar is evidently albite; and the very small amount of the third felspar may, with fair probability of correctness, be designated as oligoclase. The felspar, as a whole, is a microcline-perthite.

The abnormal structure of this felspar, as indicated by the variation in the angles of extinction, shows quite clearly how very disturbed the conditions were under which these pegmatite veins were formed, in connection with metamorphic action. The great constancy with which these irregularities of structure occur in felspars of this kind in different localities, shows, moreover, that the processes of formation have also some degree of uniformity in their action.

I carried out a quantitative analysis of this sample, with the following results :—

No. 9.—MICROCLINE-PERTHITE.

$Si.O_2$	...	...	...	63·55
$Al._2O_3$	...	...	...	20·36
$Fe._2O_3$	...	...	...	·tr
Ca.O	...	...	...	·35
Mg.O	...	...	...	·20
K_2O	...	...	...	12·00
$Na._2O$	...	...	...	3·52
H_2O	...	...	...	·52
				100·50

Hygroscopic moisture	...	...	·31
Sp. grav. ...	...	... ...	2·573

The Mg.O and some of the H_2O in the above can be referred to talc, a few flakes of which occur in the sample. Some of the combined water belongs to kaolinised parts of the felspar. Disregarding these extraneous constituents, the remainder can be calculated out as potassa, soda, and lime felspars, in the molicular proportions of 2·040, ·904, and ·052 respectively. The last probably represents the third felspar, which I have mentioned as being determinable in the thin slices. Assuming it to be an oligoclase, and to have a normal constitution—for instance, of Alb. 3 to An. 1—I may then say, with some reasonable probability of being not far from the truth, that this microcline-perthite is composed of microcline, albite, and oligoclase, in the proportions of 10 : 3·6 : 1· nearly; or, taking the two latter felspars together, the proportion between microcline and albite, + oligoclase, would be nearly as 2 : 1.

This fairly agrees with the mental conception which I have formed by an inspection of the thin slices under the microscope. The sketches given in Plate IV. differ from this in so far that, as I intentionally selected a part of each slice in which the albite veins were more strongly formed than elsewhere, a false proportion between the two felspars may seem to be indicated.

Still further up Watts Creek from the contact I found some interesting massive crystalline-granular rocks, which are worth notice as being of a type which is occasionally, though rarely, met with in the intrusive areas of this district. The rock is exceedingly tough, and difficult to prepare as a thin slice. Under the microscope I found it to be composed of felspar and amphibol, with a little reddish-brown mica and quartz. The mica appears to have been of the first consolidation, but there is so little difference in the three minerals that I cannot feel confident on this point. The mica is reddish-brown in colour and not deep in tint, and it is dichroic in shades of the same to colourless. It is largely chloritised, and otherwise does not call for further notice.

The amphibol is of a peculiar character. It occurs broadly-bladed to fibrous. There are no defined crystals, but masses, which, when cut across by the slice, show the characteristic prismatic cleavage of amphibol on a minute scale. When lying more or less in the plane of the slice the long narrow blades rarely have the same direction, but lie across each other and extend to different lengths. In places the mineral forms bundles of long and very attenuated prisms, which, extending to different lengths, give the mass a ragged-ended appearance. This mineral is faintly pleochroic, and the obscuration angles reach in the highest measurements 18°. In places I have observed a mass which, although fibrous, shows twinning, the composition face of which crosses all the fibres, which reach as parts of the same mass on each side. This suggests that the bladed or fibrous structure has been superadded upon the original condition of the mineral. There are no traces of the form of augite in the masses of this mineral, and it can therefore scarcely be a true uralite, to which it has much resemblance, but more probably one of the amphibols similarly altered.

The felspars are all triclinic, but very few show any well-defined bounding planes. Their structure is very varied, as well as compound. Some crystals are twinned according to the Albite law, others according to this and also to the Carlsbad law. The greater number have either portions in which the lamellæ differ in width from the others, or extend only partly across the section. Perhaps half the individuals in a slice are compounded according to the Pericline law, in addition to the other two forms. These felspars have brilliant chromatic polarisation, and the appearance, physically and optically, of the basic Labradorites and the Anorthite felspars which I have observed in similar rocks at the Sheep Station Creek Gap, in the Swift's Creek district.

I could obtain but few obscuration measurements, but those confirmed the general conclusion, being, in the zone $OP - \infty \overline{P} \infty$, 24° to 31°, and in three sections approximately near $\infty \breve{P} \infty$, 30°, 33°, 37°. A slice digested in hydrochloric acid showed this felspar to be much attacked, but not completely destroyed.

The quartz is in large amount as an original residuary constituent filling spaces in the manner usually seen in the quartz diorites, to which group I assign this rock.

About three miles from the Ensay ford there is a small outcrop of schists, which is an unusual occurrence in the upper part of Watts Creek. I collected two samples. One is finely foliated and dark in colour, with rarely small orthoclase crystals forming bulges in the foliations, which are rather fibrous in places, and show also plates of dark-brown mica and scales of talc. Examined in thin slices, this rock proves to be composed almost wholly of pinite material, together with numerous flakes of brown magnesia iron-mica. With polarised light the slices have much resemblance to serpentine. This rock, therefore, is a variety of pinite schist. The second sample is foliated, lighter in colour and showing small grains of quartz and felspars in the foliations. It is composed, according to microscopic examination, of much pinite, which is partly the result of the alteration of orthoclase, the remains of which can be plainly seen in some of the masses. The mica is more or less converted into a pale slightly dichroic chlorite. The quartz is in foliations, separating the other constituents. This rock is therefore a variety of those quartzose schists which I have before described; and here again it is seen that there are two varieties of these schists analogous to the quartzose and argillaceous sediments.

The line of section crosses the high range at the sources of Watts Creek, where the Ensay and Gellingall track descends from it to a small stream before ascending the dividing ridge which falls toward the Wilkinson River. The granitic rocks continue from the sources of Watts Creek to this stream, where as I have already said, at p. 71, there are traces of sedimentary rocks. On the eastern side of this small stream there are some very interesting rocks of the Diabase group, which are evidently intrusive into the crystalline-granular acid rocks, and which extend over a large tract, probably not less than a square mile in area. There are several varieties of these rocks, of which I collected samples, the examination of which gave the following results:—

38.—This rock has a black colour and micro-porphyritic structure, as seen in a hand sample. Under the microscope the ground-mass is found to be composed of—(*a*) traces of micro-felsitic basis; (*b*) innumerable colourless acicular crystals lying at all angles; (*c*) very numerous rounded grains of devitrified magma; (*d*) very numerous crystals and grains of iron ore (magnetite or ilmenite), in clusters or groups; (*e*) many brown-coloured bladed crystals, which are sensibly pleochroic in shades of brown to colourless.

The obscuration in some is straight, and in others inclined. The mineral is therefore monoclinic; and when the slice is examined by a higher objective, it is seen that cross sections have the prismatic angles of amphibol, some with the planes ∞P only, others with those of ∞P and $\infty \bar{P} \infty$ combined. The same examination shows that many of the crystals are spindle-shaped, or perhaps with very steep pyramidal planes, the ends of most being ragged. This mineral is clearly an amphibol. It is the largest of the constituents of the ground-mass, and one of the most numerous. There are finally (*f*) minute grains of yellowish augite.

In this ground-mass are porphyritically—(*g*) a few completely serpentinised olivine crystals; (*h*) prismatic crystals of augite, which are almost colourless and non-pleochroic. The extinction angle is as high as 40°. Groups of crystalline grains of the same augite also occur. Both the olivine and the augite are quite free from inclusions. (*i*) Very irregularly-formed felspars, as to which all that can be said is that they are triclinic. This rock is an "Olivine diabase porphyrite, with accessory amphibol."

A second sample I found to have the following composition. The ground-mass is much altered, but it can be seen to be made up in great measure of minute prisms and fragments of felspar. They are extended in the direction of the edge $\infty \bar{P} \infty (100)$- $\infty \breve{P} \infty (010)$. In the least altered individuals I observed that the obscuration angle is high, indicating, probably, a Labradorite felspar.

In this ground-mass are—(*a*) large, very cavernous augite crystals, some of which are twinned in the usual manner. These are of the first consolidation, but there is also a later generation of augite, in well-developed short prisms, with the planes ∞P (110)— $\infty \breve{P} \infty$ (010)— $\infty \bar{P} \infty$ (100).

These crystals contain magnetite, and also colourless granules of magma, arranged in concentric lines of growth. The earlier augite crystals contain much fewer inclusions. (*b*) Rhombic pyroxene, both in irregular-shaped masses and prisms with rectangular terminations. This pyroxene is very fibrous, in some sections roughly fibrous, of a brown colour, and markedly dichroic in shades of brown and brownish yellow. The absorption is $c > b > a$. It does not contain any inclusions. It is traversed across the prism by flaws, from which alteration extends on either side. The smaller prismatic crystals, which may possibly be of a second generation, resemble the crystals of enstatite, which I have observed in the Diabase porphyrite at Buchan.

As the monoclinic and rhombic pyroxenes are about equal in amount, this rock can be considered to stand midway between Diabase and Norite.

Other samples are of very light colour, with outlines showing of felspar crystals. One sample I found to be composed of a ground-mass of triclinic felspars. In this are other triclinic felspars, as porphyritic crystals, but much altered to epidote. Besides these there is a little iron ore, but neither augite nor any other bisilicates. Traces of viridite and very numerous small apatite prisms complete the composition.

I also examined a sample which resembled the above; but the ground-mass in this case consists of small felspars and innumerable rounded granules of coloured doubly-refracting material, apparently devitrified magma. In this are traces of porphyritic plagioclase felspars, and also masses of epidote crystals and crystalline grains, which, I think, probably replace augite. These interesting rocks are also to be classed with Diabase, and the two types which occur here remind one, in some of their features, of those palæozoic Diabases which have received from Gümbel the names respectively of Proterobas and Leukophyr.

The Diabase rocks which I have now briefly noted have, in some respects, a strong family resemblance to the Diabase porphyrites of the Buchan district, and may be thought perhaps to represent one of the deeper-seated masses with which such palæozoic lavas have been connected.

I may now note further that in the line of this section, and between the Wilkinson and Tambarra Rivers, there is a second considerable exposure of porphyritic rocks, which, I think, will be found to belong to the above group, as I have provisionally noted in the section.

There remains but little to notice in the final part of the section. The massive intrusive rocks extend, only broken by the porphyritic Diabases which I have referred to, from the summit of the divide west of the Wilkinson to the summit of the mountains on the eastern side of the Tambarra River, where they are capped by tertiary basaltic sheets, and succeeded to the east by well-marked members of the Buchan beds, including both the fragmental, tufaceous and marine limestones of that series. In a former description of the Gellingall area I stated that the Buchan beds at that place were laid down on the granitic rocks.* Since then I have seen some reasons to doubt that such is the case, but that the positions of the two formations are perhaps more probably due to faulting. At present I must leave the matter uncertain.

The description of the samples collected in this final part of the section will conclude the account which I have to give of the rocks met with in its course.

39.—The granitic rocks are exposed in the bed of the Wilkinson River, where the Gellingall track crosses it. They are traversed by several basic dykes, and by joints, one set dipping S. 30° W. at 45°, and the other to N. 30° E. at 27°. The thin slice which I prepared shows—(*a*) an iron magnesia-mica, which has been almost wholly converted into chlorite, with exclusion of ores of iron; (*b*) felspars of two kinds, of which orthoclase is one, extending over a considerable part of the slice in large masses, and having in parts veinlets of a second felspar; it also includes mica and a few small well-formed plagioclase crystals, small serpentine pseudomorphs and quartz grains; (*c*) Triclinic felspars occur in large imperfectly-shaped crystals, some of which have been broken or have been rounded off; (*d*) quartz is in moderate amount, as the residual constituent. The most peculiar feature of this rock is the

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* Notes on the Devonian Rocks of North Gippsland, Geological Survey of Victoria Progress Report, Part V., p. 117.

occurrence of a number of oval or irregularly-shaped serpentine pseudomorphs, in which no trace of the original mineral remains. Did they occur, for instance, in a basalt, I should feel very little doubt as to their representing olivine. This rock is probably a granitite.

40.—I collected this sample on the summit of the mountain, on the eastern side of the Tambarra River, where it shows out in large masses. It has the following composition:—(*a*) Mica, which is reddish brown with ordinary transmitted light in basal sections. In those parallel to the "c." axis it is dichroic, when examined over the polariser, in shades of brown and yellow. The only inclusions are magnetite crystals. The alteration is to chlorite. (*b*) Orthoclase. (*c*) Triclinic felspars, in crystals, which are better formed than the orthoclase, and compounded according to the Albite law. The few measurements of obscuration angles which I could obtain were not satisfactory, being in the zone $OP - \infty \bar{P} \infty$, between 2° 30′ and 24°. The alterations of all the felspars are micaceous. (*d*) Residual quartz, of the usual kind in such rocks. (*e*) A little apatite, and rarely titanite. This rock is also a granitite.

Principal Characteristics of the Rocks.

I have now described at some length the mineral composition of the rocks which I have found along a line of section crossing the Ensay district. These rocks fairly represent the formation of the whole district, of which Ensay is the central part.

It will now be well, for the sake of clearness, to summarise the principal and characteristic features of these groups of rocks, before proceeding to consider how they are related to each other.

It is to be first noted that the sediments which I have described have not the normal mineral character of the least altered Silurian formations of North Gippsland. These latter are best seen in tracts where there are no signs of the nearness of intrusive plutonic masses—as, for instance, in the valleys of the Wongungarra, or the Thomson River below the crossing of the Walhalla-road.

The mineral condition of the argillaceous and arenaceous beds in such localities is most certainly not such as one can imagine to have been originally that of the Silurian sediments when lying still, undisturbed, in a horizontal position; but it is also far removed from the condition of those formations which have been subject to regional or contact metamorphism.

Broadly speaking, so far as my investigations have yet gone, the Silurian sedimentary rocks of Gippsland may be arranged under three types. The first is that of the Argillites, or those beds which are found where there are no signs of intrusive masses of plutonic rocks, and which, therefore, are least altered. The changes which I have observed are usually some degree of induration by silica, and the conversion of the argillaceous material into some mineral allied to chlorite. The second type is that represented by the well-known rock Hornfels, and includes the contact schists. In such rocks the argillaceous material has been converted into mica, which most frequently is a brown magnesia-iron mica with a subordinate potassa-mica. These rocks are far more indurated by silica than the argillites, and the original clastic grains of quartz are frequently surrounded by secondary silica, oriented in accordance with the older grains. The third type, which departs most in mineral character from the normal argillites, includes the so-called Regional Schists. In this group, the first sign of alteration is the minute wrinkling of the argillites, and the appearance of a silky micaceous lustre on the planes of bedding or of cleavage. Silica is also eliminated in the conversion of the argillaceous material into mica, and becomes deposited in strings or lenticular masses in or across the beds. The ultimate result of this type of metamorphic alteration is mica schist and gneiss.

The distinction between the argillites and the metamorphic schists, contact or regional, is that in the former the argillaceous material is converted into some mineral allied to chlorite, while in the latter it has been converted into mica.

The distinction between the contact and regional schists is the more foliated structure of the latter, and the prevalence in them of an alkali-mica.

Strictly speaking, all the schistose rocks which I have spoken of in this paper should be considered as metamorphic, but I have found it more convenient to separate the beds on the western side of the Tambo River, and to treat them as being sedimentary. In outward general appearance they are recognisable as being part of that great series of slaty and sandstone rocks, which I have spoken of under the general term Silurian Argillites. But their inner structure differs much from that of the normal type, and a principal distinction is that the argillaceous part has been converted almost wholly, if not entirely, into minute flakes of mica.

In some respects the less altered beds, and specially those which are minutely "spotted," resemble some of the less altered of the contact schists.

As a rule, the quartz grains of these beds have been little, if at all, affected, except in so far that in places they appear to have been arranged with their longer diameters in line, probably by pressure.

The least quartzose and the most altered of these beds, approach in their microscopical characters near to a mica schist, in which the structure is very minute; that is to say, they retain the outward general appearance of the argillites, but have been so far metamorphosed that there has been produced in them the structure and composition of a mica schist. In other words they are phyllites.

The rocks which, in accordance with the distinction I have now drawn, are to be considered as the true metamorphic schists of Ensay, are found in three main varieties. The *first* includes the quartz schists and the fine-grained mica schists; the pinite schists form the *second;* and the *third* includes the gneiss. The somewhat peculiar rocks found at Contentment Hill connect the phyllites and the mica schists.

The quartz schists always have either a magnesia-mica or its alteration-product, chlorite. An alkali-mica almost invariably occurs in connection with the small pinite masses and veins in these schists. These constituents would bring such a rock in its unaltered state within the term Mica-schist rich in quartz. But as I have found in almost all cases, in addition to the above-mentioned constituents, more or less of a triclinic felspar (albite or oligoclase), the schists might be considered even to be a variety of a very siliceous gneiss. Yet, as the micas are never absent, while the felspars are in some cases wanting, I think the term Quartzose Mica-schist is the most appropriate.

The quartz of these schists is peculiar, and its study has raised questions which it is not easy to answer satisfactorily. The schists are metamorphosed sediments, and of all their original constituents one might expect to find the quartz to be least altered. I have observed that in the contact schists, for instance in Hornfels, the clastic origin of the quartz grains is always more or less perfectly recognisable. But in the Ensay schists this is not the case. They are eminently schistose, and, broadly speaking, the quartz and the mica form separate foliations. Frequently the quartz is in crystalline grains, whose form is rudely rectangular. In places the sections of these grains merely touch each other, while in others they overlap in the direction of the foliation. In other cases the foliation is continuous or even branching, the quartz being traversed by cross-flaws. Such observations point to the grains being flattened parallel to the foliated structure, and to be probably, in some cases at least, discoidal in form. In some slices I have found all the quartz to be evidently of the same period of formation, as, for instance, where inclusions or fluid cavities are of the same character throughout the thin slice. I note such an instance wherein numerous fine, colourless, hair-like microliths lie in the quartz veins throughout the slice, and have all of them a uniform direction. In a few cases I have been able to distinguish two generations of quartz, and in others I have observed small rounded granules of quartz included in the larger grains of the foliations.

I have thus been led to the conclusion that during the metamorphism of these once sediments the original quartz grains have been taken into solution, and then finally redeposited between the micaceous foliations.

It seems to me that the silicification of these rocks could have scarcely been effected by extraneous solutions permeating them as a whole, for in such a case one should, I think, expect to find general and similar effects throughout. Such has not been the case in this instance ; but, on the contrary, one can observe that there are still two main varieties of these schists corresponding to the arenaceous and argillaceous sediments, and therefore the conclusion may be perhaps justified that the silica, if taken into solution during the metamorphic process, was, as they ceased, again redeposited mainly in the sets of beds from which it had been derived. If this view proves to be maintainable, it will have a strong bearing upon other questions as to metamorphism which await solution in the Omeo district as well as elsewhere.

The fine-grained mica schists show somewhat similar features, but as they are much more micaceous than quartzose, the peculiar appearances which I have just noted are not so apparent.

The pinite schists, so far as concerns the principal constituent, are evidently pseudomorphic, and it is probable that they are so after magnesia-mica mainly. In the examples which I have examined microscopically I have found two kinds of mica, in addition to the pinite material. One is a brown magnesia iron-mica, and the other an alkali-mica. The latter is in many cases, but not in all, greatest in amount, and is evidently in some instances of secondary origin. The analysis of the pinite schist shows that it is not far removed from the composition of the pure pinite mineral. The pinite in these schists when seen under the microscope and by polarised light, especially in slices across the foliations of the rock, has a "meshed" appearance, resembling that of serpentine, to which mineral it has also a resemblance macroscopically when the rock is examined on a cross fracture. In places these schists contain masses of alkali-mica flakes, and more rarely colourless, divergent, or fan-shaped clusters of talc plates.

On the whole, I can see no more probable conclusion than that these pinite schists are pseudomorphic alterations of a schist rich in magnesia-mica. The conversion of magnesia-mica to pinite has been recorded by Blum, Dana, and Vom Rath,* and it may have been the case here on a large scale. Yet I must notice, as not falling in with this view, that I have not met with a single instance in all the thin slices which I have prepared and examined wherein magnesia-mica has been partly, or indeed, so far as I could see, entirely converted into anything else than chlorite. That is to say, in all the slices I have referred to there have been numerous individuals of magnesia-mica, either intact or partly chloritised; others wholly converted into chlorite; but not one single flake which showed a partial conversion into pinite, such as is so commonly the case in the felspars. Therefore the complete proof of the origin of the pinite is still wanting.

The gneissic schists are characterised by the prevalence of a monoclinic potassa felspar, often in porphyritic crystals, or that mode of occurrence which gives occasion to the term "Augen-gneiss" of the German writers. This orthoclase has been the first formed of the felspars in

* Quoted by Roth, *Allgemeine Chemische Geologie,* Vol. I., p. 332; Blum, *Pseudom,* I., 79, and III., 142; Dana, *Amer. J. of Sc.* (3), 8, 449, 1874; Vom Rath, *Zs. Geol. Ges.*, 27, 382, 1875.

these rocks, for it is very frequently crushed, broken, worn at the edges, and generally showing the effects produced by long subjection to heat, and also physical movements of the mass in which it existed in a crystallised form. Fragments of orthoclase also occur "jammed" into corners or included in the residual quartz.

The triclinic felspars are almost always in smaller and better-formed, much-compounded crystals.

It is characteristic of these gneissic schists to have two kinds of mica.

The earlier-formed one is a magnesia-mica, much poorer in iron than that of those gneisses which I have found elsewhere in the district as margins to the massive intrusive rocks. This mica of the gneissic schists is usually in the foliations with the felspars, but is also to be found included in the quartz. The second mica is a colourless alkali-mica, such as I have already mentioned when speaking of the mica schists, and I think that in many cases it is a secondary production. It is very characteristic of these gneisses that some of their constituent minerals have been altered to pinite. Some of the felspars certainly have; cordierite, also, so far as one can judge from pseudomorphs, and perhaps in the largest measure the magnesia-mica, which in an unaltered state is still plentiful in some of the foliations.

Many of the gneissic schists are so massive that it is only when they are examined *in situ* on the large scale that their character as metamorphosed sediments, and not varieties of igneous rocks, can be fully recognised.

Aplite is the first of the igneous rocks which I have to notice. Rosenbusch* defines aplite as a very fine-grained rock composed of quartz, orthoclase, plagioclase, and potassa-mica. Pegmatite includes the coarser-grained varieties. He includes both under the section "Muscovite granites." He notices as an exception the occurrence of magnesia-mica in the aplites of Cornwall.

My own observations in the Australian Alps show me that there are here also instances of aplites which have either magnesia-mica together with a potassa-mica or alone, but in all cases the former is in very small amount.

Besides the essential general characteristics of this rock, —namely, a paucity, or even almost absence, of mica, with

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* *Physiographie der Massigen Gesteine*, p. 19.

felspars and quartz all combined in a holocrystalline structure —the aplites at Ensay are marked by the abraded, fractured, and eroded state of the felspars. Both the orthoclase and plagioclase crystals show these signs of violence, and of long-continued action of the molten, or pasty and still moving, magma. Of the two the potassa felspar has usually been the first formed.

These appearances accord with my observations that the veins and masses of aplite were forced when in a plastic state into the already metamorphosed sediments. One may in some measure imagine what must have been the pressure and the temperature to which these rocks were then subjected by considering that at that time the locality in question was part of the plane of contact between the Silurian sediments and the invading plutonic masses.

With the aplites must be classed the pegmatite veins, for their distinction is mainly one of structure. There is, however, this distinction to be noted as regards Ensay: In the pegmatite veins the constituents are much larger individually than in the aplites, but the felspars do not form separate crystals, but are in compound cleavable masses. I have very rarely found any other felspar than an orthoclase or microcline-perthite. In the aplites, however, the monoclinic potassa and the triclinic soda-lime felspars have most frequently, if not always, been formed independently of each other.

The massive intrusive rocks of the Ensay district are of the quartz-diorite group. They are massive holocrystalline, and have either a magnesia-iron mica or hornblende, or both together. The samples which I have examined from Ensay do not differ materially from those collected elsewhere in the district, as, for instance, at Noyang.

The Ensay dykes belong evidently, with the exception of the rarely-occurring basalts, to two classes which correspond to the massive quartz diorites and to the massive diabases of the district respectively. Of the two groups the Diabase dykes are the younger.

Still more recent are the dykes of basalt, which may probably be referable to the time of the miocene volcanic lava flows of Gippsland.

I have not thought it necessary to enter into a longer description of the dykes found at Ensay than was necessary to bring them into relation with the other rocks. My principal object has been to work out, so far as I could do, the relations of the three great groups of sedimentary, metamorphic, and massive intrusive igneous rocks.

The Relation of the Rock Masses to Each Other.

At Ensay, as elsewhere in North Gippsland, the oldest rocks which can be discovered are members of the great series of auriferous argillites and sandstones, which is with fair certainty referable to the lower Silurian age. When a lengthened section is examined in almost any tract in the Gippsland mountains, it soon becomes clear to the observer that these sediments were once continuous in a crushed and folded condition throughout, but that by the combined action of faulting, denudation, and erosion, this continuity has been broken, so that while in places the whole country, down to some given datum line, shows no other formations than these tilted and slightly metamorphosed sediments, in other places their merest traces remain as distorted and fractured contact schists attached to the massive plutonic rocks which have invaded them.

In other papers upon the geology of North Gippsland I have insisted upon the clear evidence there is that the plutonic rocks have disturbed and metamorphosed the Silurian sediments, and to a greater or less extent melted off and absorbed, not only the lower part of the folds into which they had been previously forced, but also, so far as is yet known, every portion of the older formations, whatever they may have been, upon which they were laid down.

It is possible to note, by a few striking geological features, the sequence of the terrestrial movements which are indicated by the folding and crushing together of the Silurian sediments, their metamorphism and invasion by plutonic rocks, their denudation, and the subsequent laying down upon them of other formations, both sedimentary and volcanic.

In North Gippsland the Silurian formations, as a whole, have been folded more or less sharply together. The next succeeding sediments—namely, those of Middle Devonian age—have not been so generally and regularly affected; for while at Tabberabbera the beds have been folded much as have been the Silurians, the limestones of Buchan or Bindi remain comparatively level, as compared with the acutely folded older strata adjoining and inferior to them.

The Upper Devonian sediments, which are next in order, are entirely discordant with those of Middle Devonian age, and are in most places but little disturbed from a horizontal position.

The four groups—Lower and Upper Silurian, Middle and Upper Devonian—all show a marked decrease in mineralisation in the ascending order. Some of the nearly horizontal beds of the Iguana Creek Upper Devonians are little more than indurated clays or friable sand-rock.

So much in brief as to the sediments. Between the acutely folded Silurian and the much less folded Middle Devonian sediments there intervenes, in the chronological arrangement, as in the field, an immense thickness of igneous rocks, whose lower members rest upon the denuded edges of partially metamorphosed Silurians, while the upper beds pass as tufas into the Middle Devonian marine limestones of Buchan.*

On the grounds which I have now very briefly stated, I place the folding of the Silurian sediments and their invasion by plutonic masses at the close of the Silurian age. The Devonian volcanic rocks clearly followed this invasion, and I think that they may prove to have been connected with a second great series of younger igneous rocks, which are to be found in different parts of Gippsland, rising through both the Silurian sediments and the older plutonic masses. The younger igneous rocks are in most cases porphyritic, and I note, as instances, The Sisters and Mount Leinster, near Omeo, and Mount Taylor, near Bairnsdale. These younger plutonic rocks are probably all older than the Upper Devonian age, for the last named mountain is still capped on its denuded summit by nearly horizontal beds of the Iguana Creek series.†

Of the formations which I have now noted there are found at Ensay only the Silurian sediments, the older plutonic masses, and the metamorphosed representatives of the former. The later plutonic rocks are not met with, nor any of the Devonian sediments.

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* "Notes on the Devonian Rocks of North Gippsland"—Geological Survey of Victoria, Progress Report, I., p. 117. "Notes on the Diabase Rocks of the Buchan District"—Transactions of the Royal Society of Victoria, Vol. XVIII., p. 7.

† Geological Survey of Victoria, Progress Reports, II. p. 63, and III. p. 211.

It is to the close of the Silurian, or to the commencement of the Devonian, age that for the present I refer the igneous and metamorphic rocks of Ensay.

It remains now for me to consider what may have been the sequence in which the present relations of the Ensay Rocks have been brought about.

Although the sediments on the western side of the Tambo River are not continuous with the schists at Ensay, yet an examination of both groups *in situ*, and of samples in thin slices under the microscope, leaves no doubt in my mind that the latter are the very much metamorphosed forms of sediments which represented the latter. The schistose rocks of Contentment Hill, some of the very fine-grained mica schists at the Little River, and the altered sediments whose traces now only remain at the sources of Watts Creek, supply intermediate stages connecting the extreme examples. With these exceptions, the sedimentary rocks have been completely denuded on the eastern side of the Tambo River from the country crossed by the section.

The most interesting part of the locality, and the one to which I have desired to direct attention, is that at the junction of Watts Creek and the Little River. It is there that the schists have been preserved from denudation, either by having formed a depression below the general plane of contact, or by having been let down by faults. It is immaterial which may be the true explanation. That which is material is the very instructive manner in which the schistose and igneous rocks are associated. At first sight it seems that they are in complete confusion, but on further examination this seeming disorder is capable of explanation.

It is to be borne in mind that this locality is, as I have before said, part of the plane of contact between the sediments and the invasive igneous rocks. Taking a general view of the whole of the Australian Alps, I find that this plane of contact is a most irregular one. Its highest and lowest limits are beyond an accurate determination, for to estimate them it would be necessary to have a knowledge of the faults which have disturbed the continuity of the contact plane, of the probable thickness of the sediments where the contact is deep below the surface, and of the amount denuded from the highest points of the now protruding plutonic masses. The Ensay district is a good example of the difficulties in the way of such a determination. The Silurian beds at the west side of the Tambo River are at its level, while on the east side the massive igneous rocks rise in a vast tract of mountains to some 4000 feet higher in the Nunnyong tableland. One cannot tell to what depth the contact plane sinks on the western side of the Tambo River, or to what former elevation it rose at Nunnyong on the north-east.

The plane of contact is as irregular in the small scale as in the large. In the few places where I have been able to inspect it in vertical sections I have observed that the invasive plutonic rocks have affected the sediments in a manner which I can best illustrate by likening it to the action of warm water upon masses of ice. They appear to have eaten their way upwards in an irregular manner, leaving portions of sediment hanging down or detached in the heated materials.* That this action has been accompanied by great pressure of the molten masses against the sediments is evidenced by the fractured and, so to say, "dog-eared" state of the beds where they strike or dip against the former, and by the constant occurrence of masses and veins of the intrusive rock penetrating the sediments.

It is not necessary to consider whether this pressure was by expansive forces acting from beneath upwards, or whether it was by the downward pressure of parts of the earth's crust upon the molten masses, or by both combined. All that I am concerned with now is to point out the fact, that the action of the invasive plutonic rocks has been to force themselves, or to be forced, into the lower parts of the sediments, and to gradually metamorphose, melt off, and absorb them.

As seen at Ensay, the first igneous rocks which were forced into the sediments as veins and masses were varieties of aplites, which either penetrated between planes of bedding (foliation ?) or through cross fractures. In some places these aplite veins are very numerous, so that in a horizontal section they appear as small isolated masses surrounded by the schists, or as veins crossing or apparently interfoliated with them.

Following the aplites were those masses of plutonic rocks which are now the holocrystalline quartz-mica diorites.

The whole complex of rocks, metamorphosed sediments, veins, and masses of aplite and quartz diorite have been

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* I have given a sketch of such an occurrence at p. 77, Progress Report, Geological Survey of Victoria, Part II.

crossed by dykes of quartz porphyrite, and still later by dykes of diabase, finally in tertiary times by a few dykes of basalt.

The confused manner in which the various classes of rocks are "jumbled" together at Ensay, often within the space of a few yards, is due to their being part of an approximately horizontal contact plane, wherein they have been all welded into a complex whole.

Regional and Contact Metamorphism.

An important question now awaits some reply, What has caused the peculiar metamorphism of the Ensay sediments? That is to say—Why is it that, although in contact with intrusive igneous masses, metamorphism has, in this instance, converted the sediments into mica schist and gneiss, and not, as is the case in other intrusive areas in Gippsland, into rocks of the hornfels type?

It seems that there may be two alternative replies, one being that the schists were regionally metamorphosed before the plutonic masses invaded them, and the other that they are no more than abnormal instances of contact action.

The schists at Ensay are most probably the metamorphosed sediments of the district. Their mineral and structural character is that of the regional schists of Omeo, and not that of the contact schists. It seems that they were metamorphosed before they were invaded by the plutonic rocks, yet, like the contact schists, they are most altered in the neighbourhood of the igneous masses.

Any explanation which is satisfactory must reconcile these seeming contradictory phenomena.

I have already drawn attention, at page 110, to the three types of more or less metamorphosed Silurian sediments in North Gippsland, and of which the argillites are the least altered. Their molecular re-arrangement—that is to say, the re-crystallisation of their argillaceous parts—is one of the lesser stages of metamorphism as I observe it in this district. I note, further, that it is clearly connected with the folding together of the strata; for rocks of this class, which have been most disturbed, folded, and crushed together, are also most altered in their mineral structure. This may be observed in wide tracts, where there are no surface indications of the proximity of igneous rock masses to which such alterations might be attributed.

It might be thought that such mineral alterations as those I allude to in the argillites might be produced by the percolation downwards of surface waters. No doubt the action of such mineralised waters must not be lost sight of in any hypothesis which proposes to account for the present condition of rocks at the earth's surface.

But an explanation relying upon such solutions as a principal cause of even the lesser metamorphic changes will not account for the connection there is between the molecular regeneration of the sediments and the disturbance, dislocation, and compression to which they have been subjected. Nor will an explanation which relies upon the action of heated mineral waters from below be more satisfactory, and for the same reasons. The structural changes which the mineralised beds show point to other causes, which must be considered. It seems to me that an hypothesis to be satisfactory, in conforming to observed facts, must not overlook the forces brought into play during the vast tilting, folding, and especially crushing, to which, in Palæozoic ages, the Silurian sediments were affected: that is to say, during those periods of time when the mineralisation of the strata was effected.

It is quite certain that in Gippsland, at the close of the Silurian age, gigantic movements of the earth's crust folded the sediments together, and crushed them close. This certainly produced an amount of motion in the rocks which, within reasonable limits, it is difficult to overstate; and the question then is: What did this movement result in beyond the physical effects which can be seen still impressed upon the stubborn but bent and contorted strata?

In following out this train of thought one is easily led to the reply, that those vast movements must have generated an amount of heat proportioned to their own extent.

It must be borne in mind that the mere pressure of formations lying upon each other does not seem capable of producing such changes as those I refer to in the argillites of North Gippsland, even when many thousands of feet of beds are horizontally upon each other. But it is different where pressure causes the forcible movement of the rock particles among themselves, and especially the folding of the strata. It is under such circumstances that pressure can generate metamorphic action, and especially when the sediments acted upon are still permeated by the waters of the oceans in which they were laid down.

The sedimentary crust of the earth in Gippsland was subjected to such conditions as those I have just referred to at the close of the Silurian age, and they imply pressure, heat, mineralised waters, and vast periods of time, in fact all that which is requisite, so far as we know, to produce metamorphic action and mineral regeneration.

It appears to me to be very significant, when looked at from this standpoint, that the most crushed and contorted rocks in the Gippsland Alps are to be found in the area of regional metamorphism; in other words, where the sediments have been most dislocated and compressed, there it is that metamorphism has been most intense.

According to these views, the mineralisation of the argillites and the regional metamorphism of the sediments at Ensay and Omeo are respectively earlier and later stages of the same process, which, for want of a better term, might be spoken of as dynamical metamorphism in contradistinction to contact metamorphism.

These views lead to the further conclusion that places such as Ensay, wherein the sediments have been converted in limited areas into mica schist and gneiss before their invasion by the plutonic rocks, were localities in which the movements of the strata were greatest, where the temperature was consequently higher than elsewhere in the distorted crust, and where, as a direct consequence, metamorphism reached extreme stages.

Moreover, it seems to me to be quite conceivable that, under such conditions, those localities would be most readily invaded and absorbed by the plutonic rocks if the invasion was part of the same great range of operations.

As I see the evidence to be obtained in the Ensay district, dynamical metamorphism—as I have defined it—first produced an alteration of the sediments to the condition of argillites, next to phyllites, and finally to mica schist and gneiss.

The schists then being invaded by the plutonic masses were no doubt further affected by contact metamorphism; but in what manner, or to what degree, I am not at present in a position to state. Possibly some further light may be thrown upon this very obscure subject by work which still remains to be done as regards the Omeo district.

I have now briefly stated the hypothesis which I have ventured to bring forward as explaining the seeming anomalies of the Ensay schists. The belief that the crushing together of the strata has produced sufficient heat to set up metamorphism, is not at all new. Among others, Mallett worked it out to a great extent, and it seems to be now gaining ground among geologists in a somewhat modified form. The views which I have now recorded have been slowly forced upon me, so to say, during the progress of my investigations into the geology of the Gippsland Alps during many past years. If they have a foundation of truth, they will be maintained; if otherwise, then, no doubt, justly they will fall to the ground. It is well that I should mention that I have, in formulating them, relied upon more than the evidence of the Ensay district alone. I have, to some extent, been influenced by evidence as yet unrecorded from the Omeo district. It might perhaps be thought that it would have been better to have waited until that evidence had been worked out, and laid before this Society. But in working out the Ensay evidence I found that I had before me just those problems in miniature which confronted me at Omeo on the large scale, and I therefore briefly sketched the results arising, not only from my Ensay work, but also from that in the Omeo district. Since the work which relates to the latter area consists mainly in the analysis and microscopical study of rocks collected there, it is not likely that the general conclusions to which the field work has led me will be in any great degree altered.

Conclusions.

The general results arrived at in the preceding pages may be shortly summed up as follows:—

(1.) Two kinds of metamorphism may be distinguished—dynamic metamorphism, or the effects produced by heat, resulting from vast movements within the earth's crust, upon the sediments and the mineralised waters included in them; and contact metamorphism, or the effects produced on the sediments by masses of intrusive igneous rocks.

(2.) At the close of the Silurian age the sedimentary crust of the earth was tilted, folded, and crushed over an enormous region in the Australian Alps.

(3.) The sediments were metamorphosed during these movements. They were generally converted into argillites, and where the movement was greatest into mica schist and gneiss. The Ensay area is an instance of the latter.

(4.) Connected with or following these results of dynamical metamorphism, the more or less altered sediments were invaded from below by molten masses, which acted especially upon such areas as those referred to in conclusion 3, and also generally upon the argillites, producing the contact schists.

(5.) The period when the Ensay schists were formed may be placed at the close of the Silurian age, and in any case cannot be later than the close of the Middle Devonian period.

EXPLANATION OF PLATES III. AND IV.

Fig. 1. Horizontal section of schists at Ensay, about eight feet in width. (*a*) Schist, (*b*) quartz vein, (*c*) crystalline-granular intrusive rock.

Fig. 2. Horizontal section showing relation of schist and pegmatite vein. (*a*) Schist, (*b*) pegmatite, (*c*) aplite.

Fig. 3. Horizontal section of schist and crystalline-granular rock at Ensay. (*a*) Schist, (*b*) crystalline-granular rock.

Fig. 4. Microscopical section of microcline-perthite prepared from principal cleavage. (*a*) Microcline, (*b*) albite, × 55.

Fig. 5. Microscopical section of microcline-perthite prepared from second cleavage. (*a*) Microcline, (*b*) albite, × 55. The engraving gives the impression of striation in this albite, which is incorrect.

Figs. 4 and 5 drawn by polarised light.

Plate I.

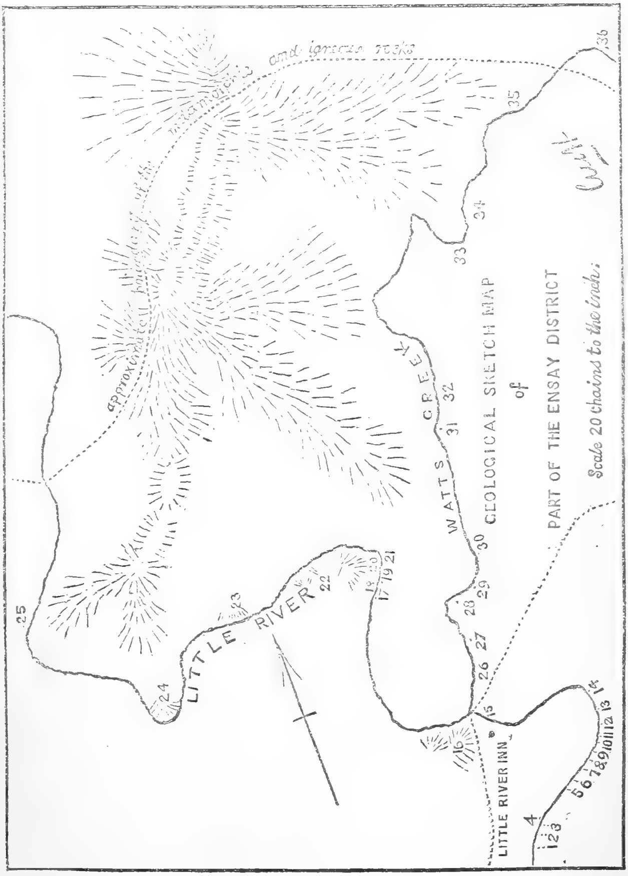

GEOLOGICAL SKETCH MAP
of
PART OF THE ENSAY DISTRICT
Scale 20 chains to the inch.
WATTS CREEK
LITTLE RIVER
LITTLE RIVER INN
approximate boundary of the metamorphic and igneous rocks

Plate II.

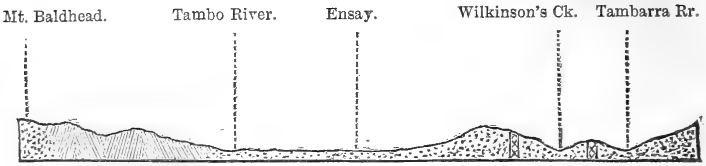


Diagram Section from Mount Baldhead to East of the Tambarra River.

Silurian — Igneous and Metamorphic — Diabase

Scale { Horizontal eight miles / Vertical 22,500 feet } one inch.

Plate III.

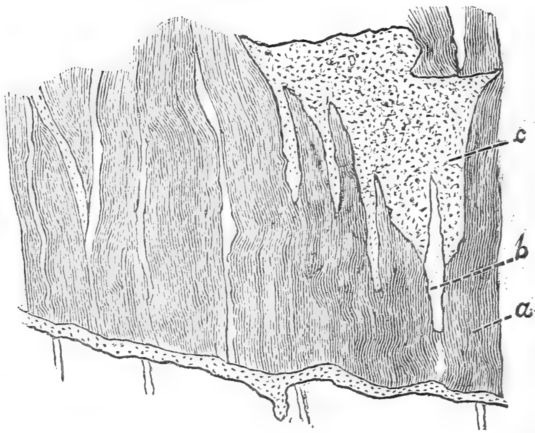


Fig. 1.

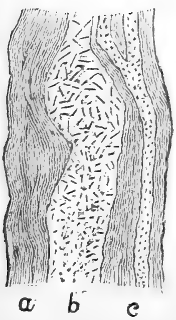


Fig. 2.

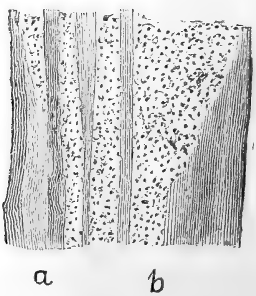


Fig. 3.

Plate IV.

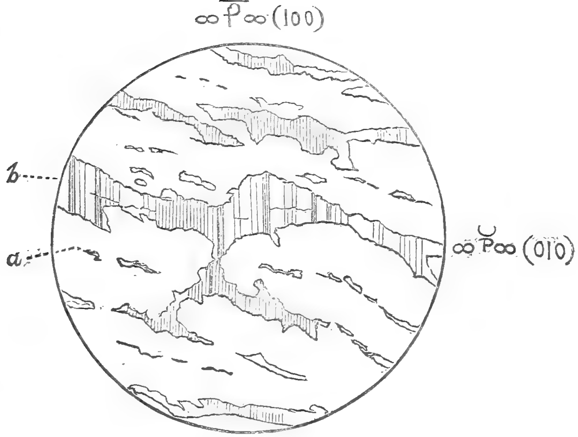


Fig. 4. × 5

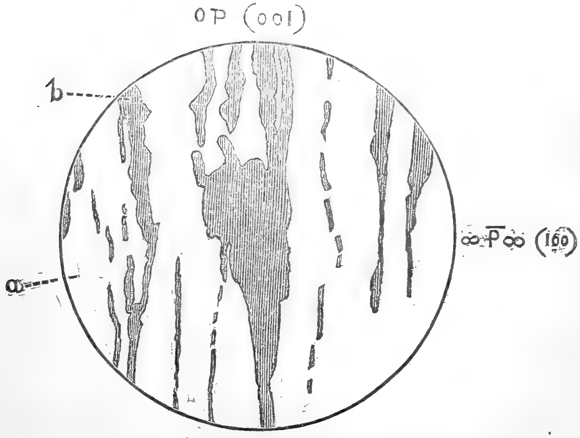


Fig. 5. × 55.

Art. XII.—*Descriptions of New, or Little Known, Polyzoa.*

Part IX.

By P. H. MacGillivray, M.A., M.R.C.S., F.L.S.

[Read 12th November, 1885.]

Family Gemellariidæ.

Dimetopia hirta, n. sp.

A form of *Dimetopia* has been sent to me by Mr. J. B. Wilson, which, although allied to *D. cornuta*, ought to be described as a new species. The cell aperture is rounder below, the margin much thicker, and the spines much more developed. Of these there are one or two on the lower margin, three above, of which the middle is longest, and three or four on each side; the uppermost usually situated further back, and directed more posteriorly.

Family Notamiidæ.

Calwellia gracilis, Maplestone.

Zoœcia very long and slender; anterior surface flattened; a short, thick process, supporting an avicularium, on each side above.

Portland, Mr. Maplestone; Port Phillip Heads, Mr. Wilson.

This species, which seems to be very rare, was described some years ago at the Microscopical Society by Mr. Maplestone, but his paper has not been published. It differs from *C. bicornis* in the zoœcia being longer, very much more slender, and flat in front. The branches are also more straggling.

Family Cellulariidæ.

Menipea funiculata, n. sp. Plate I., Fig. 8.

Zoarium continuous, dichotomously branched, branches narrow, margined by radical fibres. Zoœcia multiserial, elongated, aperture large, elliptical, with a slightly-thickened margin, and overlapped by a large sacculated fornix. On the marginal cells there are three spines at the upper and outer angle, and one at the inner; in the central cells a single spine at each side; a sessile avicularium (usually absent) attached to the upper and outer angle of the lateral zoœcia; a sessile avicularium on the front of each zoœcium, except the lateral, usually close to the peduncle of the fornix of the adjoining cell. Zoœcia posteriorly quadrate, smooth, or faintly longitudinally sulcate. Oœcia prominent, rounded, smooth. The radical fibres forming the lateral bundles spring from the lower part of the back of the cells.

Port Phillip Heads.

Closely allied to Busk's *M. benemunita,* but distinguished by the absence of the two avicularia on the front of the central zoœcia, and the different form of the fornix.

Caberea Darwinii, Busk.

In the Challenger Polyzoa, Mr. Busk describes and figures a form from New Zealand under this name, which, he says, is identical with that previously described in the *British Museum Catalogue* as *C. Boryi*, and marked on the plate *C. patagonica.* It is not uncommon in Victoria, and I quite agree with Busk in considering it as distinct from the European species. It is characterised by the zoœcia being narrowed downwards, the lower parts and sides of the area filled in by a granular layer, with the edge of the aperture finely crenulated. In perfect specimens the fornix is of large size, filling the whole aperture, except the part corresponding to the mouth. It is nearly straight above, with frequently a small process or spur projecting upwards, and the large, downwardly extending lamina has a peculiar helicoid marking, with the spiral turned inwards. Busk does not describe or figure this appearance, showing the lamina as plain, but there can be no doubt of the identity of the species. A somewhat similar, but less developed mark, is seen in an English specimen of *C. Boryi.* In older specimens the edge of the lamina is usually worn off, and it then has a reniform or hammer-shaped appearance. The ovicell when young has the margin smooth, but this gradually becomes surrounded by a thickened band.

C. glabra, n. sp.

Zoarium expanded, flabelliform. Zoœcia biserial, slightly narrowed below, area partly filled in by a smooth plate.

Fornix, with a thick peduncle, the lamina usually expanded chiefly downwards, reniform or hammer-shaped, two spines at the outer angle above, and one, frequently of enormous size, from the peduncle of the fornix. Lateral avicularia, small; central avicularia large, irregularly placed above or below the peduncle. Zoœcia posteriorily elongated, smooth or faintly sulcate. Vibracular setæ, serrated. Oœcia rounded, arcuate or irregular in outline, flattened in front, with a thickened marginal rim.

Port Phillip Heads.

Differs from *C. Darwinii* in the smoothness of the lamina filling in the area. It is closely allied to the European *C. Boryi*, in which the cells are shorter and broader, and which has a thickened smooth band round the edge of the aperture. The oœcia are at first nearly smooth at the upper edge, but gradually develop a thickened rim.

Family FARCIMINARIIDÆ.

Farciminaria simplex, n. sp. Plate I., fig 1.

Zoarium dichotomously branched, internodes long. Zoœcia much elongated, narrow, separated by raised, slightly crenulated or smooth margins. Oœcia very large, globular. No avicularia.

Port Phillip Heads.

This species differs from the others previously described in the absence of avicularia and of spines or processes of any sort on the separating margins of the zoœcia. The oœcium is of great size, occupies a distinctly bounded space between the extremities of two cells. It is smooth, globular, but when dried becomes wrinkled, and has a depression round the upper edge and sides, showing the marginal walls, owing to the shrivelling of its delicate outer envelope, which seems to be separated by some distance from the inner part.

Family BEANIIDÆ.

Beania conferta, n. sp. Plate I., fig 5.

Zoœcia large, each connected with six others by very short tubes; six large spines above, of which two from the summit project directly upwards, a similar pair (one on each side), originating a little farther back, pointing in the same direction, and the third pair, arising opposite the lower edge of the mouth, projecting upwards and forwards, and curved inwards at their bases; on each side of the aperture a double row of long, stout spines, the outer directed forwards and outwards, and the inner series, alternating with these, arching close over the front of the cell, and meeting in the mesial line. Dorsal surface smooth, glassy; in many, especially the marginal cells, a round mark on each side towards the base, probably marking the attachment of a radical fibre. No avicularia.

Portland, Mr. Maplestone; Port Phillip Heads, Mr. J. B. Wilson.

This species is readily distinguished from the other Australian forms by the closeness of the cells, the six large spines at the anterior extremity, and the absence of avicularia. The peculiar arrangement of the marginal spines, alternately directed outwards and inwards, is not constant, but when present is very striking. It is evidently very closely allied to the form described from Algiers by Mr. Hincks as *Diachoris hirtissima*, var. *robusta*, from which it differs in having two instead of three superior spines, and in the total absence of avicularia. This and Heller's *D. hirtissima*, in both of which avicularia are absent, clearly prove the invalidity of *Diachoris* as a genus, the only reason for distinguishing which from *Beania* consists in the presence of these organs.

Family FLUSTRIDÆ.

Craspedozoum, n. genus.

Zoarium uni- or bilaminate, in strap-shaped divisions; each branch bordered in its whole extent by a bundle of radical fibres springing from the bases of the lateral zoœcia. Zoœcia quadrate, area partly filled in by a thickened lamina. Oœcia external, with a thickened rim or band at or near the margin, usually produced at the summit into a more or less prominent point.

In the *Annals and Magazine of Natural History* for August, 1881, Mr. Hincks described and figured a remarkable form from near Port Curtis as *Membranipora roborata*, pointing out at the same time the doubtfulness of its position, its characters being intermediate between those of *Flustra* and *Membranipora*, and agreeing with Gray's *Flustramorpha* in the presence of a lateral band of radical fibres. This species occurs also at Port Phillip Heads and Portland (Maplestone). At the Heads two other species have also been found, agreeing with it in their essential generic characters, but differing in being unilaminate, and in some other points of specific value. There can be no doubt that these ought to be formed into a distinct genus, to which also, probably, Mr. Busk's *Flustra membraniporides* (*Challenger Polyzoa*, p. 54) belongs. He, however, neither figures nor describes the marginal bundle of radical fibres, which, however, may (as in *Menipea*) not be of generic value. *Flustramorpha*, if Busk's species are rightly referred to that genus, has a totally different zoœcial structure.

C. ligulatum, n. sp. Plate I., fig. 3.

Zoarium unilaminate; branches narrow, dichotomously divided. Zoœcia multiserial; a small spine at each upper angle. A single avicularium, with a triangular-pointed mandible at the base of each cell. Oœcia rounded above and slightly pointed, with a thickened margin, usually produced into a small point at the summit.

Port Phillip Heads; New Zealand, Miss Jelly.

Differs from *C.* (*Membranipora*) *roboratum* in being unilaminate, the branches being very much narrower, and consequently the rows of zoœcia fewer, and in there being only one avicularium at the base of a cell.

C. spicatum, n. sp. Plate I., fig. 2.

Zoarium unilaminar, dichotomously divided, the branches narrow. Zoœcia multiserial, rhomboidal; area broadly elliptical, the margin thickened, crenulated, the plate filling in the lower part finely granular; the central zoœcia with a spine on each side above, the marginal with two on the outer angle above, the lower of which is much larger. A sessile avicularium at the base of each zoœcium. Oœcia not prominent, nearly quadrate, a thickened band from each side of the opening passing upwards and inwards, meeting in the centre and produced upwards as a long sharp spike.

Port Phillip Heads, Mr. J. B. Wilson.

Family ESCHARIDÆ.

Schizoporella pulcherrima, n. sp. Plate I., fig. 6.

Zoœcia separated by narrow raised lines, broad and nearly flat, surface traversed by faint lines converging from minute pores or depressions at the margin; mouth very wide, edge thickened, contracted towards the base, and the lower lip forming a slightly hollowed sinus or nearly straight. A broadly elliptical avicularium placed obliquely on each side of the mouth.

Port Phillip Heads.

The structure of the mouth approximates to that of *Gemellipora striatula.*

Smittia cribraria, n. sp. Plate I., fig. 7.

Zoarium encrusting. Zoœcia large, separated at the growing edge by raised lines; towards the older parts distinct, but the separating line not raised; whole surface occupied by large, closely set foramina, largest at the circumference; a hammer-shaped denticle in the oral sinus. Oœcia rounded, smooth or pitted, sub-immersed.

Port Phillip Heads.

On one or two of the zoœcia there is what seems to be an avicularium with an enormous flat, rounded mandible similar to that described by Hincks on *Lepralia bifrons.*

Family ADEONIDÆ.

In the Challenger Polyzoa Mr. Busk proposes a new genus *Adeonella,* which with *Adeona* (including *Dictyopora*) he places in a family Adeoneæ. Under *Adeonella* he places a number of species previously undescribed or referred to the old incongruous genus *Eschara.* These, as mentioned by him, differ from *Adeona* chiefly in the absence of a flexible stem, agreeing in the presence of distinct avicularian cells, oœcial cells and in the curious articular processes of the avicularian mandibles, as well as in the presence of a suboral pore or cluster of pores. These pores, however, as recently pointed out by Mr. Waters (*Quart. Journ. Geol. Soc.,* Aug., 1885), differ essentially in several of the species. In one group, to which he would restrict the generic name, represented here by *A. platalea* (Busk) and *A. dispar* (M'G.), the pore is formed by the growth of the peristome, and in reality opens into its tube external to the operculum and true mouth, while in the other group the pore or pores open into the body-cavity below the mouth. These last, with *Adeona* and *Dictyopora,* in which the structure is similar, he refers to *Microporella.* I cannot agree with this view, and it seems to me that Busk is quite right in forming a separate family. The characters chiefly are that in the Adeonidæ, in addition to the ordinary zoœcia, there are other purely avicularian cells. There are no external oœcia, as in *Microporella*, but the ova seem to be developed in specially modified zoœcial cells (not, however, yet observed in some of the species), and all the avicularian mandibles (whether from the avicularian cells or from the zoœcial avicularia) have a small process at each articular angle which, so far as is at present known, is confined to this family. Busk's *Adeonella*, however, ought to be divided into two, the *Adeonellœ* proper, where the pore is external; the other where it is zoœcial (opening into the cavity of the cell). The species here described belong to the second group, to which the generic name *Adeonellopsis* may be given. It would include also *Eschara mucronata* (M'G.)

Adeonellopsis foliacea, n. sp. Plate II., fig. 1.

Zoarium large, foliaceous, lamina twisted so as to form a cellular mass. Zoœcia rhomboidal, quincuncial, separated by distinct grooves; surface pitted, a median pore or pores (when fresh obscured by the epitheca); mouth arched above, straight below; a median avicularium below the mouth, with the mandible pointed directly upwards and projecting beyond the lower lip, and one smaller on each side (occasionally absent), directed inwards and slightly downwards. Oœcial cells very large, convex, pitted and tuberculated like the ordinary cells.

Westernport, Mr. J. B. Wilson.

Mr. Wilson has also sent me a variety in which the zoarium is not foliaceous and cellular, but with branches narrower, anastomosing, and much twisted. The zoœcial characters, however, are identical; Both forms attain a large size, the specimen of the first, which is broken, measuring 6 in. x 5 in., with a depth of nearly 4 in.

A. latipuncta, n. sp. Plate II., fig. 5.

Zoarium expanded, foliaceous, simple or convoluted. Marginal cells convex, with a large circular area on the front, occupied by a cluster of 6—10 fimbriated pores; mouth arched above, slightly hollowed below. Older cells with the edge much raised, leaving the perforated area in a depression. A large central avicularium below the mouth with the long narrow mandible pointed directly upwards. Colour, yellowish brown.

Port Phillip Heads.

A. parvipuncta, n. sp. Plate II., fig. 4.

Zoarium small, erect, branched, the branches broad and flat. Youngest zoœcia elongated, convex, mouth arched above, straight or slightly projecting below; a small, round, smooth or dentate pore below the mouth. Older cells distinct, rhomboidal, quincuncial, the lateral parts much raised, convex, inclosing the mouth and pore in a deep hollow; pore single, and usually elongated and denticulate in the zoœcial cells, in the oœcial, which are broader, the depression is occupied by several denticulate or stellate pores. Small, triangular avicularia scattered on the edges of the cells and frequently on slight eminences by the sides of the mouth. Large vicarious avicularia, with triangular mandibles, arranged on the free edges of the branches.

Port Phillip Heads.

A. australis, n. sp. Plate II., figs. 2 and 3.

Zoarium erect, formed of irregularly-divided branches, flat, narrow, twisted, and truncate at the extremities. Zoœcia rhomboidal, convex, narrowed below, separated by finely crenulated, raised lines. A small, central, stellately perforated depression. Mouth arched above, straight below. A median avicularium below the mouth, with the triangular mandible directed obliquely upwards; frequently another avicularium towards the base of the cell. Oœcial cells very broad, with the mouth much wider and shallower, not very convex; occasionally with two lateral oral avicularia in addition to the central one. Vicarious avicularia very large, with triangular mandibles, interspersed among the zoœcial cells, but more frequent on the margins of the branches.

Port Phillip Heads. Common.

Bracebridgia, n. gen.

Zoarium erect, bilaminate, branched. Zoœcia distinct, entire; mouth subcircular, with an internal denticle; peristome raised, thick. Avicularian cells on the free edges of the lobate branches, the triangular mandibles with a projecting articular process at each lower angle. Oœcia ?

B. pyriformis, Busk, sp. Plate II., figs. 6 and 7.

(*Mucronella pyriformis,* Challenger Polyzoa, p. —)

The Zoarium attains a height of one or two inches, and consists of flat branches with lateral lobes, the various branches usually more or less twisted on themselves. The Zoœcia are pyriform, separated by deep grooves; the mouth is subcircular, with a broad denticle internally and occasionally a small apiculate process on the lower lip. There is an elevated ridge round the mouth, the two sides meeting below the lower edge and continuing down the cell as a central elevation. The surface is smooth, or, especially in young cells and on the raised portion, minutely granular. As age advances the divisions between the cells become much fainter, the cells themselves are squarer, and the mouth appears as a circular opening surrounded by a broad tumid margin. Many of the cells are also completely closed. One very young specimen (fig. 7) rises as a small bifid lobe from an encrusting base. Towards the edge of the encrusting part many of the cells are closed or not properly formed, while both external and internal to these are some where the mouths have clear, narrowly elevated margins, with an apiculate mucro below and, in a few, a broadly elliptical avicularium across the front of the lower lip. I have not seen these oral avicularia in any other specimen. On the free edge of the lobate branches, in most specimens, there is a single row of avicularian cells.

This species, which is common, has been described by Mr. Busk in the Challenger Polyzoa, and doubtfully referred to *Mucronella*. There can, however, be no question that it ought to form the type of a new generic group, and I have much pleasure in associating it with the name of my friend, Mr. J. Bracebridge Wilson, who has done so much to advance our knowledge of the marine zoology and botany of Victoria. Its systematic position, however, is doubtful, and it ought perhaps to be included in the Escharidæ.

Family CELLEPORIDÆ.

Pœcilopora, n. genus.

Zoarium erect, bilaminate, branched. Zoœcia indistinct; primary mouth, with a sinus; peristome commencing as an elevated point, with a small avicularium on the summit, finally becoming a tumid, subcircular ring. Oœcia immersed, closed by a perforated plate.

P. anomala, n. sp. Plate I., fig. 9.

Of this very curious species, I have only one good specimen, for which I am indebted to Mr. Wilson, and two or three imperfect fragments. The zoarium is small, branched, bilaminate. The youngest zoœcia and those at the margins of the branches have one side produced into a long point, with a small avicularium on the inner surface at the summit. As age advances the summit disappears, and the mouth becomes surrounded by a tumid peristome, with the avicularium usually on the outer part of the ring. The pointed process, with its surmounting avicularium, seems to be formed before the operculum, as in the cells showing these parts it cannot be detected. In a few older cells, where the peristome is developed into a thick circular ring, the internal mouth can be seen with a slit on its superior side, that is, towards the *upper* end of the branches. On the basal side of the mouth is a perforated plate, which at first I thought was an ordinary zoœcial opening similar to that of *Microporella renipuncta.* It is, however, in reality the opening of the oœcium. In young cells this appears first as a cup-shaped elevation, which becomes covered by a perforated plate, and gradually sinks into the substance of the zoœcium. The most curious circumstance is that, although it would appear to be below the mouth, it is really above it, owing to the peculiar reversal of the mouth. It is evidently closely allied to *Lekythopora hystrix* (M'G.), where the oœcia and oral avicularia are similar. The shape of the operculum is similar in both, but I have not yet made the necessary examination to ascertain if the position of the oœcium in *Lekythopora* is also superior, although seemingly inferior. The two species are most remarkable, and I hope shortly to be able to give a more detailed account of their structure.

Family HORNERIDÆ.

Idmonea interjuncta, n. sp.

Zoarium dichotomously branched, branches spreading irregularly, intricate, occasionally anastomosing; numerous bundles of prismatic, calcareous, radical tubes, passing from the back of the branches, and attached either to the surface on which it grows or to other branches. Zoœcia usually four in a series, of which the inner is shortest, turned much forward, united side to side, separated by distinct grooves, surface thickly covered with projecting pores. Posterior surface finely grooved longitudinally, covered with elevated perforations as in front; surface marked by obscure, transverse, concentric ridges.

Port Phillip Heads, Mr. J. B. Wilson.

This is so close a repetition of *I. Milneana* in miniature that I was at first disposed to rank it as a slender variety of that species. It differs in being very much more slender, the branches more interlacing, the colour dirty white instead of green, and in the branches being joined to each other in many instances by the long, calcified bundles of tubes.

EXPLANATION OF FIGURES.

Plate I.

Fig. 1. *Farciminaria simplex,* natural size. Fig. 1*a*. Outline of portion magnified, showing an oœcium.

Fig. 2. *Craspedozoum spicatum,* natural size. Fig. 2*a*. Portion magnified.

Fig. 3. *C. ligulatum,* natural size. Fig. 3*a*. Portion magnified.

Fig. 4. Portion of specimen of *C. roboratum* (Hincks sp.), natural size, to contrast with Fig. 3.

Fig. 5. Zoœcium of *Beania conferta,* magnified.

Fig. 6. *Schizoporella pulcherrima*; the left-hand cell is evidently formed by the fusion of two.

Fig. 7. *Smittia cribraria.*

Fig. 8. *Menipea funiculata,* natural size. Fig. 8*a*. Portion magnified.

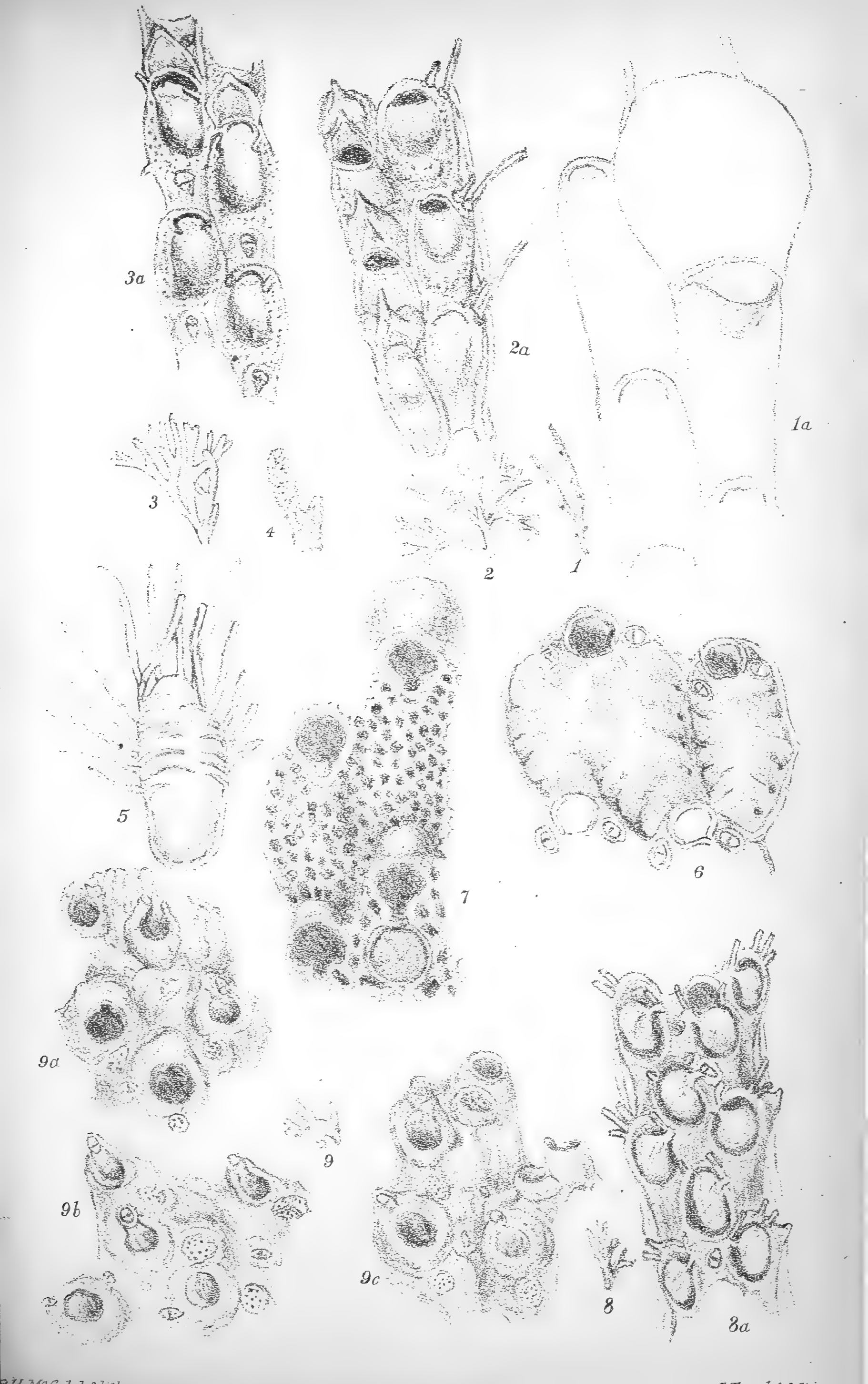
Fig. 9. *Pœcilopora anomala,* natural size. Fig. 9*a*. Portion from the extremity of a branch, magnified, one of the zoœcia showing the internal or primary mouth. Fig. 9*b*. Portion from the growing edge. Fig. 9*c*. Another portion showing the growth of the oœcium.

Plate II.

Fig. 1. Zoœcium and oœcial cell of *Adeonellopsis foliacea.* Fig. 1*a*. Avicularian cell of same.

Fig. 2. *A. australis,* natural size. Fig. 3. Portion of another specimen magnified, showing ordinary zoœcia, a closed zoœcium, and two avicularian cells. Fig. 3*a*. Another portion of the same to show an oœcial cell.

Fig. 4. *A. parvipuncta,* natural size. Fig. 4*a*. Portion magnified.



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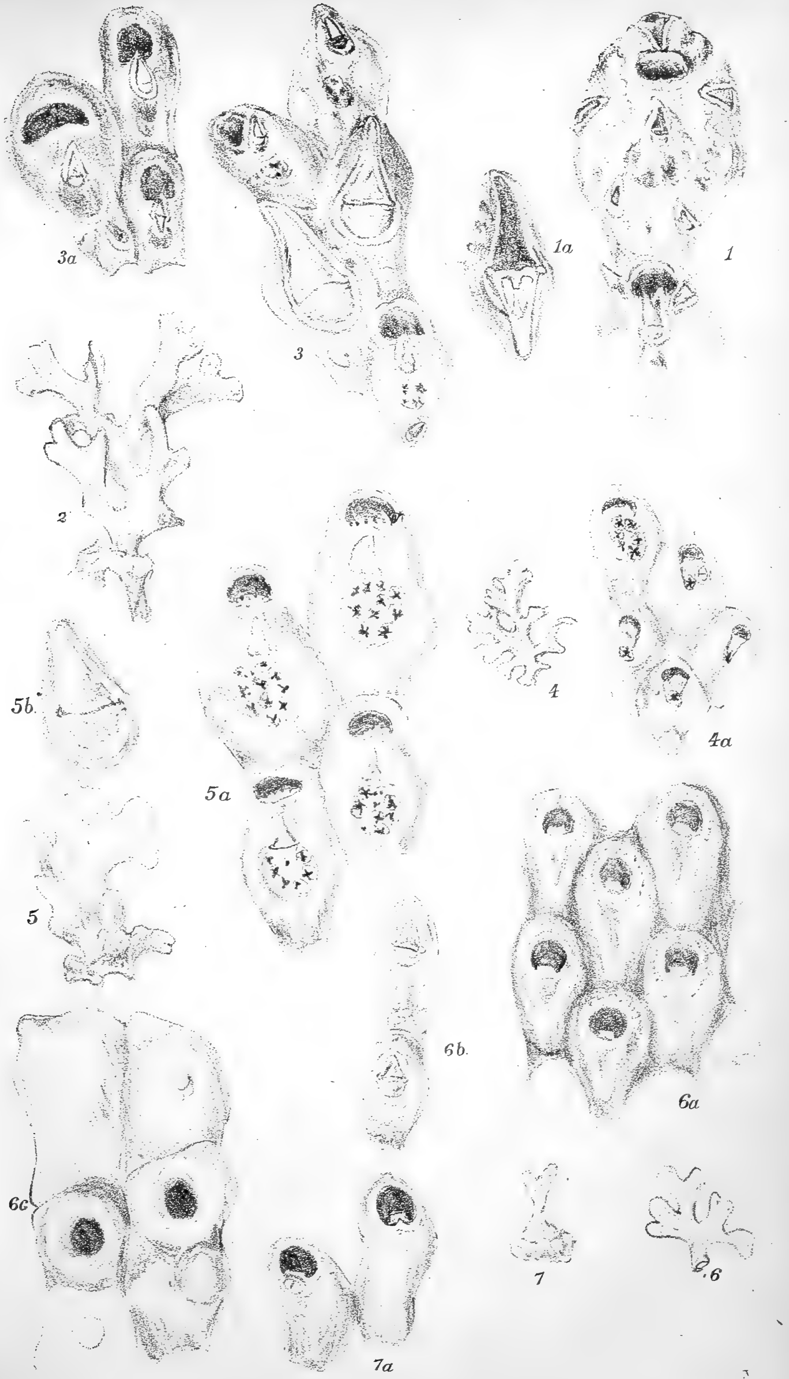

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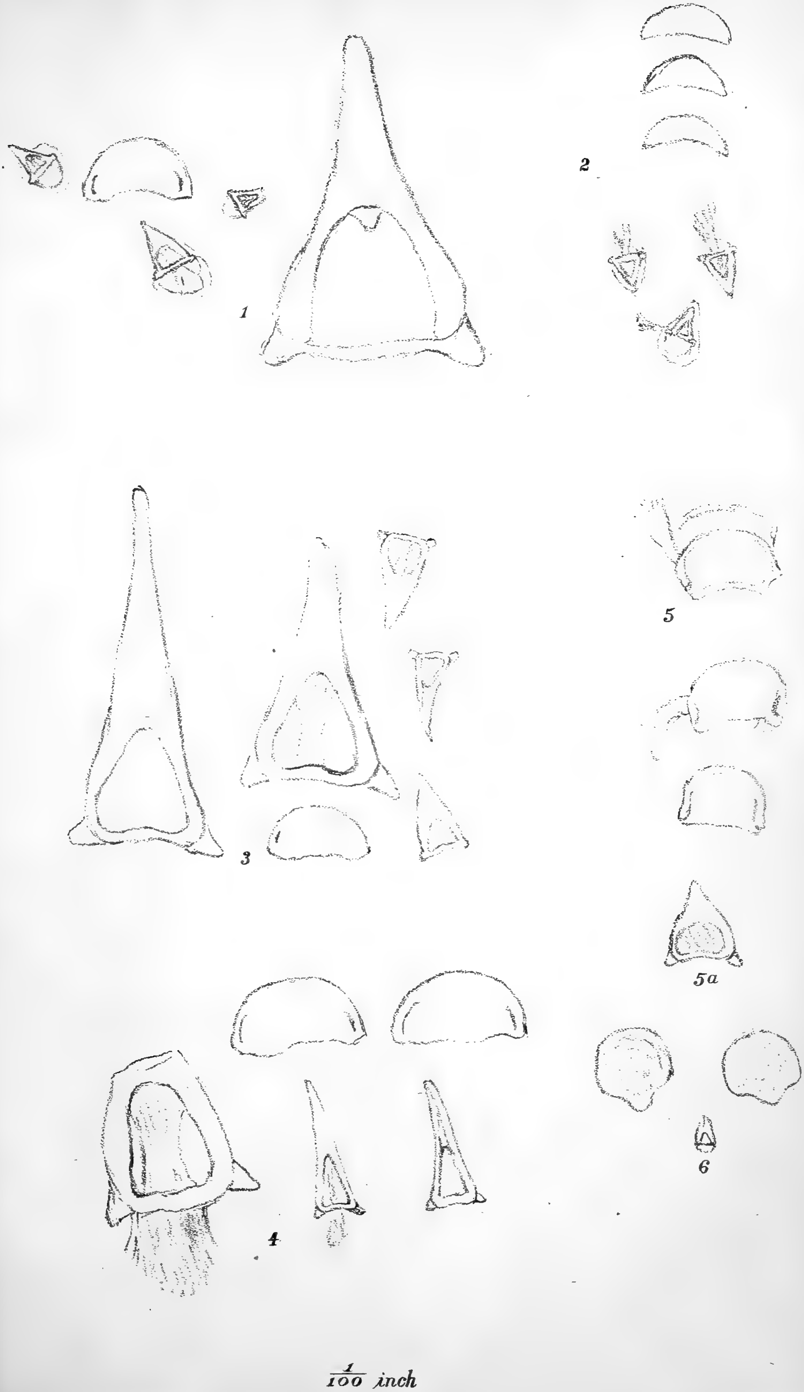

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C. Troedel & Co. im

Fig. 5. *A. latipuncta,* natural size. Fig. *5a.* Portion magnified. Fig. *5b.* Avicularian cell.

Fig. 6. Portion of specimen of *Bracebridgia pyriformis,* natural size. Fig. *6a.* Portion of the same magnified. Fig. *6b.* Two avicularian cells from the free edge. Fig. *6c.* Portion of older part of same zoarium. Fig. 7. Young specimen, natural size. Fig. *7a.* Two Zoœcia from the same, showing an apiculate mucro and an oral avicularium.

Plate III.

Chitinous parts of—

Fig. 1. *A. foliacea.*
Fig. 2. *A. parvipuncta.*
Fig. 3. *A. australis.*
Fig. 4. *A. latipuncta.*
Fig. 5. *Bracebridgia pyriformis.*
Fig. 6. *Pœcilopora anomala.*

Art. XIII.—*On an Apparatus for Utilising the Force of the Tides.*

By Mr. Lockhart Morton.

[Read December 10th, 1885.]

Art. XIV.—*On an Apparatus for Determining the Stability of Ships.*

By C. W. M'Lean.

[Read December 10th, 1885.]

Obituary.

THE HON. DAVID ELLIOTT WILKIE, M.D. Ed., AND L.R.C.S. Ed.

Dr. Wilkie was a native of Haddington, in Scotland, where his early education was obtained. He afterwards studied in Edinburgh for the medical profession, and graduated at the University of that city. Afterwards he went to Paris, for the purpose of completing his medical studies, and in 1838 he came to Australia, selecting Adelaide as his first place of residence, and coming on to Melbourne in the succeeding year. At that time the medical profession in this colony consisted of very few members, but Dr. Wilkie, after he had been here some time, induced the others to join him in commencing a medical society, which was called the Port Phillip Medical Association. In 1852 a second society—the Medico-Chirurgical Society—was formed, and in 1855 these two bodies became the present Medical Society of Victoria, of which, in 1858, Dr. Wilkie became President. In that society he took a warm interest, and frequently read papers at its meetings. He was also a regular contributor to the *Australian Medical Journal*, which in 1856 he helped to found, and which for awhile he edited. He was one of the original members of the Philosophical Society, out of which finally grew the present Royal Society, and was first its treasurer and afterwards (in 1857) its vice-president. He contributed to its Transactions frequent papers; and although some of his conclusions, especially that referring to the Yan Yean Reservoir, were curiously unconfirmed, there was no denying the great industry and care with which his essays were prepared. Dr. Wilkie was one of the first physicians to the Melbourne Hospital, a connection which, after being for some time broken, he afterwards renewed, and to the duties of which office he applied himself with a conscientious regard for their fulfilment. After several unsuccessful attempts, he in 1858 became a member of the Legislative Council of this colony for the North-western

Province. He retained his seat for ten years, during which time he became a member of a Government and Chairman of Committees; but he never showed any special liking for political life, his heart being in the study and practice of his profession, in which he deservedly held a conspicuous place, and in which he won considerable success, both generally and as a specialist, the direction of this latter being gynocology.

For several years before his visit to Europe, whither he went in November last, Dr. Wilkie had retired from very active practice, but his scientific interest in medicine never waned. His death took place in Paris on the 2nd of April of this year, at the age of seventy. The event was unexpected, as he was in very fair health when he left Melbourne.

EDWARD BARKER, M.D. Melb., F.R.C.S. Eng.

Dr. Barker was an old colonist, having arrived in Victoria in 1840, when only twenty-four years of age. He was a native of the South of England, and his medical education was received at University College, London, where he was a pupil of the illustrious Liston, and to whose example and precepts he attributed much of the interest he always took in operative and conservative surgery. His first experience here, however, was not in connection with his professional pursuits, for on his arrival he at once took up land in the north-west, where he entered upon pastoral pursuits with much energy and very profitable results. Nine years later he experienced a desire to resume the practice of the profession to which he had been trained, and although he continued a commercial connection with his squatting undertakings, he settled down in Melbourne to the regular work of medicine. In 1851 he obtained his first official position, being elected in that year honorary surgeon of the Melbourne Benevolent Asylum, then only just started. In 1852 he was chosen to a like position on the staff of the Melbourne Hospital, at that time a very small institution in comparison with its present bulk and importance. He held this appointment continuously for twenty-four years, during which period he deservedly acquired the reputation of a skilful and scientific surgeon. He was one of the founders of the Royal Society of Victoria, and also of the Medical Society, both of which grew out of the fusion of competing, but not antagonistic, associations. With the governing bodies of both societies he maintained a long connection, and of the Medical Society he was President in 1859. He assisted in starting the *Australian Medical Journal*, which has been for more than thirty years the organ of the Medical Society, and he contributed papers of a practically valuable kind both to this publication and to the earlier Transactions of the Royal Society. In 1864 he was appointed lecturer on surgery in the then recently established Medical School of the University, having during the previous year taken the degree of Doctor of Medicine. About the same time he was appointed by the Government one of the official visitors of Lunatic Asylums, and the opportunity the duties of this office afforded him of studying mental diseases caused him to become an authority in that branch of medicine. Indeed, as a good "all-round" man in the medical profession, he could not well be distanced, and his success in practice was commensurate with his ability. He was a diligent reader of medical books, and he had collected together a very valuable library of both standard authors and monograph writers. As a consulting surgeon, therefore, he held a leading position. Like many other old colonists, however, Dr. Barker did not die rich, although he was at one time regarded as one of the very successful of the early settlers in this part of the world. Perhaps he had not the special faculty of thrift, which is necessary to the accumulation of wealth; and it is certain that, in the days of his prosperity, he was as open-handed as he was warm-hearted.

He was married in 1845 to Miss Scott, who came of an old Midlothian family, and his domestic life was known to be a happy one. He had a numerous family, and two of his sons chose also the medical profession; but they both died before him, and at his death only a son and daughter survived him.

Among the many good qualities of Dr. Barker the interest he always took in the Royal Society of Victoria will be remembered not the least when his name shall have been only an historical memory. He died on the 30th of June, 1885.

JONATHAN BINNS WERE, C.M.G., J.P., &c.

Mr. J. B. Were, the third son of Nicholas Were, Esq., a landed proprietor in Somersetshire, was born at Wellington, in that county, on the 25th April, 1809. As a youth he entered the employ of a leading commercial house in the seaport town of Plymouth, with whom he continued for some years; but being possessed of an enterprising spirit, and having the command of some capital, he eventually determined to visit the colonies, in the hope that he would there find a freer scope for the use of both the one and the other.

Accordingly, upon the 25th July, 1839, he embarked for the new settlement of Port Phillip, with his wife and two young children, in a ship freighted by himself with goods suitable to the enterprise. He landed in Australia on the 15th November following, and he was, from the time of his arrival in Melbourne to the date of his death, a leading figure in its commercial world.

He received his magistrate's commission in 1840. He was one of the earliest presidents of the Chamber of Commerce. From 1841 to 1851 he was a leader in the agitation which resulted in the separation of the district of Port Phillip from the colony of New South Wales. He was on the committee of the Melbourne Hospital as far back as 1841. In 1854 he joined the Philosophical Society of Victoria, an institution which, with another, eventually merged into the Royal Society. He became a member of the council of the latter body shortly after it was established, and subsequently he was elected a life member, in recognition of the valuable services which he had rendered to it. Although of late years he had ceased to take any active part in our proceedings, he ever expressed himself as heartily interested in our work, and as well pleased to hear of our progress.

The deceased gentleman was also a member of the Royal Society of Antiquaries of Copenhagen.

Mr. Were represented Brighton in the Legislative Assembly in the year 1856, but he retired for good from politics in the following year.

He was an ex-director of the Union Bank, and was consul for no less than six different foreign powers.

He was a Companion of the Order of St. Michael and St. George of Great Britain, a Knight Commander of the Danish Order of the Danneboog, and a Knight of the Swedish Order of Wasa.

One of the founders of the colony of Victoria, Mr. Were's long colonial career was marked conspicuously by zeal in promoting the interests of his adopted country, by energy and integrity in the management of his business, and by charity and hospitality in his private life.

He died at his residence, "Wellington," Brighton, of a complication of disorders, on the 6th December, 1885, in the seventy-seventh year of his age, leaving behind him a widow—his second wife—four sons, and four daughters.

1885.

PROCEEDINGS.

ROYAL SOCIETY OF VICTORIA.

ANNUAL MEETING.

March 11*th*, 1886.

PRESENT, the President (in the chair) and 16 members and associates.

The Report and Balance-sheet for 1885 were read and adopted, as follow:—

"*Report of the Council of the Royal Society of Victoria for the Year 1885.*

"The Council has again to report the conclusion of a year marked by nothing very startling in the way either of calamity or success. It has been a time of quiet prosperity; and though it is true that only a small proportion of our Members actively join in the preparation or discussion of papers, still what has been done has been on the whole very satisfactory.

"During the year there have been elected 5 members, 2 Honorary Life Members, and 4 Associates. There are now on the Members' roll the names of 108 Ordinary Members, 18 Life Members, 7 Corresponding Members, 10 Honorary Members, 39 Country Members, and 73 Associates, making a total of 255.

"During the year there have been received for the Library 85 volumes and 518 parts of Scientific publications.

"Vol. XXI. of the Society's Transactions was issued to Members in June, 1885. Vol. XXII. will be ready for distribution in April next.

"Your Council has to report with regret the death of Dr. Wilkie, who was one of our earliest Members, and at one time an active and valued contributor to our Transactions.

"During the year there have been held 9 ordinary meetings, in addition to the annual conversazione. The following papers were read and discussed:—

"*April 16.*—'On the Examination of Water,' by Mr. Cosmo Newbery.

"*May 14.*—'Photography, Its Past and Present,' by Mr. L. Hart.

"*June 11.*—'On the Recent Earth Tremors, and the Conditions which they Indicate,' by Mr. G. S. Griffiths. 'The Atmosphere a Source of Nitrogen in Plant Economy,' by Mr. E. L. Marks.

"*July 9.*—'Evidences of Glaciation in the Australian Alps,' by Mr. J. L. Stirling.

"*August 13.*—'On the Dynamical Equivalent of a Pressure,' by Mr. Wakelin. 'On Uniformity in International Statistics,' by Mr. H. d'E. Taylor.

"*September 10.*—'The Cryptogamia of the Australian Alps,' by Mr. J. L. Stirling. 'On Fuller's Spiral Slide Rule,' by Mr. Fenton.

"*November 18.*—'The Metamorphic Schists and Intrusive Rocks of Ensay,' by Mr. A. W. Howitt. 'New or Little-known Polyzoa,' Part IX., by Mr. M'Gillivray. 'Note on the Habits of Hermit Crabs,' by Mr. A. H. S. Lucas.

"*December 10.*—'On an Apparatus for Obtaining Force from the Flow of the Tides,' by Mr. Lockhart Morton. 'On an Apparatus for Determining the Stability of Vessels,' by Mr. C. W. M'Lean.

"During the year your Council made arrangments for the full report of the discussions of the Society, and have engaged the services of an excellent short-hand writer to be in attendance at each meeting.

"The Council has continued the process of binding the valuable scientific journals and magazines which have been for some years past accumulating, and Members will see a considerable addition to the number of volumes on our shelves.

"*Report of Section A.*

"The year 1885 has been marked by increasing activity and excellence of the papers contributed.

"The attendance has been steady throughout the year. The number of names cn the list of members is now about 40.

"The following were the papers contributed :—

"Professor Kernot traced the development of the steam engine under the title of 'High-Speed Engines.'

"'Boiler Riveting.' By Mr. W. R. Rennick.

"'Long Shafting.' By Mr. C. W. M'Lean.

"'Rainfall and Flood Discharge.' By Mr. G. R. B. Steane.

"'The Cootamundra Railway Accident.' By Professor Kernot.

"'Mr. Fidler's Graphic Method for Continuous Girders.' By the Secretary.

"'Electric Systems.' By Mr. John Booth.

"'The Metacentre Balance.' By Mr. C. W. M'Lean.

"B. A. SMITH, *Hon. Sec.*"

BALANCE-SHEET.

The Hon. Treasurer in Account with the Royal Society of Victoria.

Dr.

	£	s.	d.	£	s.	d.
To Balance from last Balance-sheet				£446	17	9
„ Government Grant—Balance of 1884–85				115	0	0
„ Do. do. portion of 1885–6				150	0	0
„ Six Entrance Fees				12	12	0
„ Subscriptions—						
74 Members	£155	8	0			
1 Do. (Half-year) ...	1	1	0			
21 Country Members	22	1	0			
3 Do. do. (Half-years)	1	11	6			
45 Associates	47	5	0			
1 do. (Half-year) ...	0	10	6			
Arrears	22	1	0			
Commission	0	3	0			
				250	1	0
„ Rent and Gas				17	1	6
„ Sale of Transactions				0	8	8
„ Interest				24	14	6
				£1016	15	5

Cr.

	£	s.	d.
By Printing and Stationery	£138	13	9
„ Furniture	3	4	0
„ Books	3	12	0
„ Binding	48	6	0
„ Freight and Charges of Books and Transactions ...	5	0	9
„ Conversazione and Teas	15	16	10
„ Rates	4	13	4
„ Gas and Fuel	6	17	9
„ Clerical Assistant	36	0	0
„ Hall-keeper	6	0	0
„ Collector	28	0	5
„ Insurance	3	10	0
„ Postage	28	0	9
„ Contribution to the Davy Fund	20	0	0
„ Petty Cash, Advertising, and Sundries	6	5	0
„ Balance in Bank	662	14	10
	£1016	15	5

Compared with the Vouchers, Bank Pass-book, and found correct.

3rd March, 1886.

JAMES E. GILBERT } AUDITORS.
ROBERT E. JOSEPH }

BALANCE-SHEET.

The Hon. Treasurer in Account with the Fund in Aid of the Widow of the late Dr. Davy.

Dr.					Cr.	
To Subscriptions received per S. W. MacGowan, Esq.—				By Paid to Mrs. Davy	£50 0 0	
Collected in Victoria	£108 0 0			,, Balance in Bank	111 12 0	
Do in South Australia ...	24 8 0					
		£132 8 0				
,, Other Subscriptions		9 4 0				
,, Contribution of the Royal Society		20 0 0				
		£161 12 0			£161 12 0	

Examined and found correct.

3rd March, 1886.

JAMES E. GILBERT } AUDITORS.
ROBERT E. JOSEPH }

STATEMENT OF LIABILITIES AND ASSETS.

Dr. LIABILITIES.			ASSETS.		Cr.
To Three Debentures outstanding	£15 0 0		By Estimated Value of Outstanding Subscriptions ...		£40 0 0
,, Interest unclaimed	12 12 0		,, Do. do. Rents due		10 0 0
,, Estimated Amount of other Outstanding Liabilities	20 0 0		,, Hall, Library, Furniture		3500 0 0
,, Balance in Bank at credit of Davy Fund	111 12 0		,, Balance in Bank—Davy Fund Account	£111 12 0	
			,, Do. do. General Account	662 14 10	
	£159 4 0				774 6 10
,, Balance	4165 2 10				
	£4324 6 10				£4324 6 10

ORDINARY MEETING.

Held April 16th, 1885.

PRESENT, the President (in the chair) and 22 members and associates.

The President desired that members who had objects of scientific interest should make an effort to assist in rendering the Victorian Court of the Indian and Colonial Exhibition, to be held in London in 1886, as complete as possible from a scientific point of view.

Dr. Neild read a short obituary notice of Dr. Wilkie, who had been an active member of the society in its early days. On his motion it was resolved that a letter of condolence be forwarded to the widow of Dr. Wilkie.

The President then reported the progress that had been made in securing contributions to the Davy fund. He stated that the sum of £157 4s. had been collected by the society, and that the Government had granted £100 in addition.

Mr. COSMO NEWBERY then read his paper on the "Examination of Water." In the discussion which followed

Mr. ELLERY said that the only way to thoroughly protect our water supply was to exclude human habitations from the catchment area. He described the efforts that had been made to keep the basin of the Yan Yean free from dwellings. There was nothing, so far as was yet known, that could be added to deleterious water, so as to destroy disease germs. Perhaps lime might have that result to a small extent. He remembered that on one occasion when Dr. Gillbee was examining a hydatid sac it was noticed that the micrococci were at once killed by the addition of a drop of brandy. Perhaps there might after all be some force in the popular notion that the addition of a little spirit to water made the latter less likely to communicate disease.

Mr. E. L. MARKS said that he had long taken peculiar interest in this examination of water used for drinking purposes. In the destruction of germs he noticed that benzine had a remarkably quick, while carbolic acid had a very slow, effect.

Dr. JAMIESON said that he had been much struck by hearing Mr. Newbery confess how inadequate were the merely chemical tests of water. The presence of disease germs was scarcely a matter to be determined by the ordinary qualitative tests of a chemist. Doubtless the presence of albuminoid nitrogenous matter was a warning, but that might be abundantly present without the appearance of germs, and on the other hand deadly germs might be found where it was comparatively absent. He considered that the gelatine method of determining the bacterial energy present was a much more satisfactory test than any other; for in this way it is possible to cultivate each species free from the interference and competition of others. In Melbourne he considered that typhoid was more prevalent than in any town of England. Even if the specific poison were not present we ought to be suspicious when organic matter is present in drinking water; for even if it does not engender typhoid, it is certain to increase diarrhœa and allied diseases. No filter is of the least use in removing bacterial forms, but in its own way a filter of compressed asbestos was the best that could be had for purifying water. He had seen Mr. Newbery's experiments with benzine, and the result was certainly remarkable.

Mr. Blackett said that he always thought that bacteria were of the nature of a ferment. It was surprising that Melbourne should be so heavily visited with typhoid fever when its water supply was so pure. Pasteur has discovered that through a biscuit porcelain, under a pressure of two atmospheres, it was possible to filter out bacterial germs.

Mr. A. C. Macdonald said that the Moorabool River, which supplied Geelong with water, gathered its waters from a pig-feeding area, and the supply would not therefore be very pure.

Dr. Henry said that bacteria of typhoid seemed to grow most readily where animal and vegetable refuse were mingled.

Mr. Fenton said that the death-rate from typhoid was increasing at an alarming rate in Melbourne. Perhaps milk was the most dangerous vehicle in which the typhoid germs would be disseminated. The late Dr. Thomson maintained that the typhoid germs were absorbed by vegetable matters only from decaying animal matters with which they might happen to be in contact.

Mr. White said that possibly the germs of typhoid and allied fevers might be spread by the dust-storms, which were the plague of Melbourne. Dry dirt of all sorts gathered on our streets, on account of defective scavenger arrangements, and it was possible that the wind may blow dried, but not killed, germs into our food.

Mr. Ellery agreed with Mr. White, and noticed that in Melbourne typhoid abounded most in dry, dusty weather.

Mr. Newbery pointed out that free and albuminoid ammonia increased in the rain collected by the Observatory gauges whenever the weather was hot and dry, for the air was then charged with organic matter in the form of dust, which was necessarily washed down into the gauges. In reply to a question from a member, he stated that the disease germs were so small that they passed readily through any filter. Whether boiling would destroy their vitality he could not say, but it must certainly be looked on as to a certain extent a safeguard.

Mr. Sutherland remarked that in Melbourne, while the death-rate generally was decreasing, there was a steady increase in the deaths from typhoid. This result could not be due to any increasing neglect of sanitary precautions, for the change was certainly in the other direction. He thought that possibly the reason might be that there was a steadily-increasing population of Victorian birth. Those who came here as emigrants from other lands mostly came in the prime of life, and a large proportion would be likely to have already passed through the ordeal of typhoid, thus being, to a certain extent, preserved against it in after life. The comparative absence of typhoid in the early days of the colony might have been due to the fact that the field it had to spread in was worked out, while the rising generation has no such safeguard.

Dr. Neild replied that typhoid existed here in abundance in the early days of the colony, but it was then known as colonial fever.

The discussion then terminated.

May 14*th*, 1885.

Present, the President (in the chair) and 21 members and associates.

The President communicated a message from the Council suggesting that Messrs. H. K. Rusden and Edward Howitt should be elected Honorary Life Members, in consideration of their services as Honorary Secretaries of the Society when the duties were more arduous. After some remarks from several members testifying to their knowledge of the value of the services of these gentlemen in promoting the interests of the Society, Messrs. Rusden and Howitt were unanimously elected Honorary Life Members.

Dr. Neild, Librarian, announced that he had received from Mr. H. F. Eaton, Dr. Davy's son-in-law, a copy of J. J. Fahie's "History of Electrical Telegraphy."

Mr. Ludovic Hart read his paper on "Photography, its Past and Present."

Professor Kernot said the Society was much indebted to Mr. Marks for his paper; that photography was invaluable to all the professions, but particularly to the engineers, as it was perfectly reliable. He remarked on the fact that a photograph is evidence, which is not the case with an engraving. He suggested as an interesting exhibit a specimen of each process in the history of photography, and Mr. Hart promised such an exhibit.

Mr. White also remarked on the unreliability of any other pictorial records. Photography was of immense service to astronomers, and though the results were imperfect when clear definition of small objects was required, there was ground for hope of improvement. He thought Mr. Hart did not do justice to Mr. Osborne.

Mr. SUTHERLAND said the matter of the paper was not original. Photography was being rapidly adapted to commercial purposes, and his brother had recently patented an invention by which a printed picture could be issued within two hours after the object had been photographed.

Mr. MARKS said that many beautiful reactions in photography were worthy of detailed description, especially those by which the various rays of the spectrum, visible and invisible, affected the sensitised plate.

The Rev. J. J. HALLEY mentioned Mr. Woodbury's process of sun printing, which was invented at Eaglehawk, Victoria, but failing support here, the inventor went to London, where it was appreciated, and the necessary assistance obtained. He also mentioned the composite photograph, by means of which a typical face was obtained by the combination of several with some common leading characteristic.

June 11*th*, 1885.

Present, Mr. White, Vice-President (in the chair), and 21 members and associates.

Mr. W. K. Thomson was duly elected a member of the Society.

Mr. G. S. GRIFFITHS then read his paper "On the Recent Earth Tremors, and the Conditions which They Indicate."

Mr. ELLERY said that the seismic centre, as placed by Mr. Griffiths, corresponded with that calculated by himself and Captain Short. He said that seismic shocks were never felt at the bottom of mines, and that the motion of tall trees is less than that of short ones.

Dr. TAYLOR, F.G.S. (visitor), said the speed of an earthquake depended largely upon the strata through which it passes.

Mr. WHITE said that such computations as that of Mr. Griffiths' might be vitiated by want of uniformity in the clocks; but the time kept here is, on the whole, better than that of Europe.

Dr. TAYLOR said that the water contained in the first mile of the earth's surface acts as a sort of buffer, capable of checking the spread of the movement.

Mr. GRIFFITHS replied to the observations made.

Mr. E. L. MARKS read his paper on "The Atmosphere as a Source of Nitrogen."

Mr. ELLERY said the paper opened up a new consideration, and was worthy of experiment to test it. Certainly the atmosphere was a source of nitrogen to the soil.

Dr. TAYLOR said that in Professor's Viel's recent work it was shown that the leguminosæ have the power of enriching the soil with nitrogen.

Further discussion was postponed.

July 9th, 1885.

Present, the President (in the chair) and 17 members and associates.

The Rev. Wm. Williams was duly elected as a country member, and Messrs. L. A. Chase and O. F. Colvin as associates.

Dr. HENRY moved a vote of thanks to Mr. Selby for his handsome donation of books to the Society. Carried.

Dr. HENRY moved that the Society place on record its regret at the death of Dr. E. Barker, and express its appreciation of the services rendered by him to the Society at its origin.

Mr. BLACKETT reopened the discussion on Mr. Marks' paper on "The Atmosphere as a Source of Nitrogen in Plant Economy." He said nitrogen was being constantly taken from the atmosphere, but was never restored. Also, that when crops are repeatedly sown in the same soil without nitrogenous manures they rapidly decline in annual yield.

Mr. SUTHERLAND was disappointed that no reference had been made to the experiments of French and English chemists, which had made it tolerably certain that free nitrogen is not assimilated by plants.

Dr. JAMIESON was also disappointed. He distrusted the arguments used by Mr. Marks. The analogy of oxygen in animal bodies with nitrogen in plants was inconclusive. He thought that the leguminosæ had strong plant digestion, and could break up obstinate compounds, leaving the nitrogen free for succeeding plants. There is annually deposited over the soil of France about 24 lbs. to the acre of nitrogen in combination, in the forms of ammonia and nitric acid. Hence he saw no need to invoke the theory of free nitrogen by plants.

After a few remarks from the President,

Mr. MARKS, in reply, said the matter was open for discussion, the experiments hitherto published being unsatisfactory.

Mr. James Stirling's paper on "Evidences of Glaciation in the Australian Alps" was then read, but the discussion was postponed till the next meeting.

August 13th, 1885.

Present, the President (in the chair) and six members and associates.

The Secretary (Mr. Sutherland) read Mr. Wakelin's paper on the "Dynamical Equivalent of a Pressure."

The PRESIDENT and Mr. SUTHERLAND pointed out some fallacies in the paper.

Mr. SUTHERLAND read Mr. H. d'E. Taylor's paper on "International Statistical Uniformity."

Mr. Griffiths, Mr. Rosales, Mr. Fenton, Mr. Moors, and the President took part in the discussion.

September 10*th*, 1885.

Present, the President (in the chair) and 15 members and associates.

Mr. S. K. Vickery was duly elected a country member of the Society.

Mr. Stirling's paper on "Evidences of Glaciation in the Australian Alps" was then discussed.

The Secretary read a letter from Mr. R. A. F. Murray, in which he expressed doubts as to the evidences produced by Mr. Stirling. The discussion was continued by Mr. Griffiths, Mr. Rosales, Mr. Thomson, Mr. White, and Mr. Sutherland.

Mr. Stirling's paper on the "Cryptogamia of the Australian Alps" was accepted as read, and Mr. Fenton exhibited and explained "Fuller's Spiral Slide Rule," which elicited commendatory remarks from Mr. White and others.

November 13*th*, 1885.

Present, the President (in the chair) and 21 members and associates.

Mr. J. J. Jones and Mr. G. C. Inskip were duly elected country members of the Society, and Mr. E. M. Moors an associate.

The PRESIDENT mentioned that by private liberality the Linnæan Society of New South Wales had been presented with a hall.

Mr. A. W. Howitt read a paper on the "Metamorphic Schists and Intrusive Rocks of Ensay."

Mr. G. S. GRIFFITHS described the way in which he apprehended the sequence of events towards the close of the Silurian period. First, the flat Silurian strata under the ocean would become crumpled up by the slow contraction of the earth, producing secondly intense heat, and thirdly a state of fluidity, plasticity, and expansion in bulk. Fourthly, the upper strata would be burst through by the expanding mass below. Fifthly, the upper strata would be largely fissured thereby. The appearances described in the paper could be accounted for by these suppositions. He asked for explanation of the statement that the intrusive rocks appeared to penetrate the Silurian formations as tongues or promontories.

He would expect that in such a case the streams would cut their way down to the softer sedimentary rocks, but Mr. Howitt said that they cut down to the igneous rocks. He could understand this if the Silurian strata were horizontal with the igneous rocks underneath.

Mr. Howitt had not meant to convey that the summits of the hills of Ensay were capped with metamorphic sediments. The metamorphic rocks are not in the low valleys where the streams cut deepest. He described the relative positions of the strata in different parts of the district, and said the igneous masses from below have eaten their way up gradually. If you have igneous rocks, you have a portion of the rocks at the surface alternating with portions of sediment.

The further discussion of Mr. Howitt's paper was postponed to another occasion, when he could arrange to be present.

The President called upon Dr. M'Gillivray to read part of his series of papers on "New, or Little-known, Polyzoa."

Dr. M'Gillivray explained that the paper, being purely technical, was scarcely adapted for reading. He said he intended to complete a list of those polyzoa found in Victoria, and to publish the series of papers in Professor M'Coy's "Prodromus."

The President then called upon Mr. Lucas, who read his paper on "The Habits of Hermit Crabs," of taking possession of the shells of molluscs, illustrated by a particular case which came under his own observation.

The President asked if these habits were peculiar to the Victorian hermit crab.

Mr. Wilson thought the crab in question appeared to be in quest of a good dinner as well as a house. He had had one given to similar predatory habits, and related it proceedings.

Mr. Marks remarked on the great advantages of direct observation instead of relying upon books.

Mr. Griffiths inquired whether Australian crabs have their pincers of equal size, as stated by Mr. Lucas of his crab.

Mr. Lucas thought it likely that many hermit crabs have claws of equal size, but they can secure their food with equally or unequally sized claws. He had desired to show that these crabs, instead of being harmless and weak, as supposed, are crafty and ferocious. They appropriate the shell as a disguise in attack, and not for defence.

December 10*th*, 1885.

Present, the President (in the chair) and 18 members and associates.

Mr. F. Harding was duly elected an associate.

The PRESIDENT announced that Dr. M'Gillivray's paper on "The Classification of Polyzoa" was not completed, and therefore called on the Secretary to read Mr. Lockhart Morton's paper on "An Apparatus for Obtaining Force from the Flow of the Tides," Mr. Morton not being a member of the Society.

The SECRETARY (Mr. Sutherland) read the paper, and the President then requested Mr. Morton to explain the model of his apparatus, and to address the meeting in elucidation of his views.

Mr. ELLERY said that he thought the proposal feasible. There is no doubt immense power in tidal rise and fall, to both of which Mr. Morton's apparatus was adapted by the shifting clutch by which the action was made reversible. He mentioned another invention of Mr. D'Ebro's for utilising wave motion, which had been successfully brought into practice.

Mr. WHITE doubted whether the scheme could be made to pay. Machines for utilising tide action were common on the Rhine some years ago, but had since been quite superseded by the use of coal, which was much cheaper and more convenient. Such inventions might be useful when the supply of coal becomes exhausted.

Mr. MARKS said that the force utilised, being both vertical and horizontal, must be intermittent, and the different height of tides at different times would require further appliances to secure uniformity of power. Experiments were very desirable.

Mr. SUTHERLAND admitted the force of Mr. White's remarks, but thought it probable that new natural forces will develop when the necessity arises. One great advantage of steam power is that it is available anywhere in our towns. While that is the case no one will go to a distant tide apparatus. It certainly might be transmitted by means of electricity, which would alter the case.

Mr. WHITE was surprised when he found that the water power of Niagara was so little utilised. The great convenience of steam power gives it most important advantages.

Mr. SELBY said the cost of conveying the power is the difficulty. It had, however, been done; 40-horse power was said to have been actually transmitted 25 miles, being equal to 80-horse power at the driving end.

Mr. M'LEAN said he had never seen a clutch applied like Mr. Morton's.

The PRESIDENT said the subject was important as well as interesting. Machinery power can be concentrated so much more than animal power. Animal power for engines is now quite superseded, and wind is very uncertain; streams dry up, also; and the tides are too distant from where the force is wanted. Nothing can compete with coal for cheapness and convenience.

Mr. MORTON explained that he had provided for the vertical and horizontal force of tidal motion. He gave reasons for thinking that his clutch would not jam. It seems a pity not to utilise the tidal force at Queenscliff; but if this invention is really of no commercial value it will be useless to prosecute the matter further.

The PRESIDENT then called upon Mr. M'Lean, who read his paper on "An Apparatus for Determining the Stability of Vessels."

The PRESIDENT remarked on the importance of the subject, and the serious losses in lives and money from the neglect of it, as in the cases of the "Austral" and the "Captain." Mr. M'Lean's experiments and apparatus are calculated to prevent the recurrence of such casualties.

Mr. M'LEAN said (in reply to Mr. White) that ships were too frequently built to a model. Proper precautions are not taken to provide against shifting of cargo; much more attention is now given to the subject in shipbuilding, and this apparatus is being adopted.

Mr. WHITE attached far more value to such experiments as Mr. M'Lean had been making than to such complicated theoretical computations as Mr. M'Lean described.

Mr. ELLERY produced Mr. Verbeek's report to the Dutch Government upon the volcanic eruptions in the Straits of Sunda, which, with sundry drawings, had been sent to him by Mr. Ploos van Amstel, with a translation, which he read, of extracts from the book, which was in Dutch.

Abstract of a pamphlet on the "Eruption of Krakatau" in August, 1883, by R. D. M. Verbeek, mine engineer, Buitenzorg. Java, 19th February, 1884:—

"R. D. M. Verbeek, Esq., engineer of mines in Java, Buitenzorg, was commissioned by the Netherlands-India Government, Batavia, to investigate the nature, the intent, and the consequences of the volcanic eruptions at Krakatau. The results are given in a pamphlet as a preliminary report, and a more elaborate report is in course of publication. As that report will be accompanied by many charts and plans it will take some time before the publication will be issued. Krakatau, and various other islands in the Straits of Sunda and along the coasts, were visited by the engineer and party. As to the causes of the terrific eruptions little can be said, as is generally the case with volcanic eruptions; yet in this case something may be stated. Krakatau, with a few other volcanoes, is situated on a crevice or fissure of the crust of the earth, which runs right across the Sunda Straits, and the existence of which was suspected by Mr. Verbeek about three years ago. It is possible that along such a fissure portions of the earth now and then fall in, causing a pressure on the subterranean melted matters. Besides, along such a fissure water can have easier access to the subterranean cavities. When this water comes in contact with the melted matters steam is generated of a high temperature and very high pressure. And this steam may be considered as the chief motor of most, if not all, volcanic eruptions. There is greater probability of eruptions breaking out along such a fissure than under any other circumstances, provided always that sufficient water can percolate. As the volcanoes in the Sunda Straits have been at rest for about two hundred years, we may now conclude that the water supply during that time was insignificant, and only materially increased in the last few years. In these years several earthquakes took place along this fissure, which principally affected the lighthouse at Java's first point. The most severe earthquake took place on the 1st September, 1880; the top part of the lighthouse broke off, and the rest had to be taken down. These earthquakes were no doubt the result of subterranean changes, and it may be supposed that the fissure underwent several modifications, which allowed the sea-water to penetrate in larger quantities. In the last three years the pressure of the steam was evidently of sufficient force to press the lava upwards out of the deeper-lying lava cavities into the funnel of the crater of Krakatau, and the eruption took place when at last the steam was forced through the lava into the funnel of the crater and to the surface. A portion of the lava was at the same time carried away, and ejected in the form of fine particles of dust. The porous nature of the ejected matter—being nearly all pumice stone—is, no doubt, to be attributed to the great force with which the steam was blown through the lava. A more elaborate account of the manner in which the eruption was brought about will follow, as drawings are necessary to fully understand the matter. It is, however, to be observed that the Krakatau eruption has greatly modified our ideas in regard to the form and extent of the subterranean cavities. Assuming that there is a connection between the eruption and the increased activity of the volcanoes of the Indian Archipelago since that time, the earthquakes in Australia coinciding with the eruptions (which at any rate is a most remarkable coincidence), it follows that the cavities are much more extensive than they are supposed to be by the geologists of the present day. Krakatau was the only crater at work. The eruptions of the 26th and 27th of August were accompanied by terrific reports and atmospheric vibrations. During those days an incessant rumbling sound was heard, resembling that of distant thunder, but the actual eruptions were accompanied by sharp reports, resembling heavy cannon firing, whilst the most terrific reports were of much shorter duration, and cannot be compared to any other sound. The great distance at which the reports on the 27th of August were heard exceeds all previous experience. The reports were heard at Ceylon, in Burmah, Manila, Doreh, and Geelvink Bay (New Guinea), and at Perth (Western Australia), and at all places nearer to Krakatau. In order to form an adequate idea of the immense area over which the sound travelled, a circle should be drawn round Amsterdam with a radius of 30 degs., commencing at the most northern point, at 82 degs. N. lat.; also north of Spitzbergen; then across Nova Zembla, along the Ural Mountains to Orenburg, Tiflis, Damascus, Jerusalem, Suez, crossing the Tropic of Cancer at about 15 degs. E. long. (Greenwich); then to the most southern point at 22 degs. N. lat. in the Desert of Sahara, crossing once more the Tropic of Cancer at 5 degs. W. long. (Greenwich), close along Terro; then to the Canary Islands and the Azores, and back to Spitzbergen through the greatest portion of Greenland. It was observed that the reports were heard more distinctly at a distance than at places nearer in the same direction with Krakatau, as Anjer, Serang, Batavia. This phenomenon is attributed to the fact that in the lower strata of the atmosphere an immense quantity of ashes was existent, which could not but have the effect of deadening the sound. There is every probability that along and over this ash-cloud the sound travelled to more distant places—as, for instance, Batavia (ninety miles from Krakatau)—whilst at Anjer, being behind this ash-cloud, the sound was only feebly heard. At the time of the eruption waves of air of great length, although not audible, had a remarkable effect. The more rapid of these vibrations affected, as a matter of course, the buildings and the walls of rooms, so that objects against the walls or hanging from the ceiling began to move, and this accounts for the fact that at Batavia and Buitenzorg, at a distance of 150 kilometers from Krakatau, door and windows began to shake, the clocks stood still, and statuettes on the cupboards fell down, whilst oil-lamps came down with a sudden crash. At other places a similar effect was experienced, solely arising from the vibrations of the air, and not from earthquakes, which were never experienced with any certainty during the whole time of the eruptions. This is a most remarkable event. Moreover, the most terrific explosions produced air waves of an immense length of wave. From barometrical observations in Europe and America it was ascertained that the rapidity of these waves nearly equalled the rapidity with which sound is propelled, showing that it would take seven minutes for these waves to reach Batavia from Krakatau. The most terrific explosions took place on the 27th of August at thirty-five minutes past five, ten minutes to seven, five minutes past ten, and five minutes to eleven, Batavia time. The explosion of five minutes past ten was the fiercest, when an enormous air-wave ascended from the top of Krakatau, and in the form of a ring round that point spread along the surface of the earth, and travelled 3¼ times the entire circumference of the earth. The rapidity, as already stated, was nearly that of sound, although the waves were of a gigantic length (the length of wave of the lowest audible tones is about 20 meters; the Krakatau air-wave 1,000,000 meters). The eruptions which at first broke out above the sea, broke out probably after ten o'clock under the sea. Previous to that hour only ash, more or less moist, was ejected; but after that time a large quantity of mud, being volcanic sand mixed with sea-water, was thrown up. The northern portion of the volcano gave way before the eruption broke out under the sea, as is proved by the time that the great tidal wave submerged the 'Vlakke Hoek.' This tidal wave probably resulted from the northern portion of the volcano, an immense mass of earth falling into the sea; and where Krakatau once stood there is now water of a depth of 200 or 300 metres, whilst in the midst of this deep sea a rock remains of about five metres above the sea—truly a remarkable occurrence. The component parts of the ejected matter are chemically not sufficiently known, but the analysis that has been made proves that the products do not possess acidium silicium (kiezelzeuer) in equal quantities. The ash which Mr. Verbeek collected at Buitenzorg contained, according to the analysis, 60 per cent.; a piece of pumice-stone on the island of Calmeyer, 68 per cent.; a piece of obsidian of Krakatau, 68 per cent.; and a fine yellow ash of the east coast of Krakatau, as much as 70 per cent. acidium silicium (kiezelzeuer). Further, aluminous earth (aluinaarde), 14 to 16 per cent.; sulphurata ferrum, 6 per cent.; calx (kalk), 4 per cent.; soda, 4 to 6 per cent., and a little magnesium.

"Between Krakatau and the island of Sebese the sea is entirely filled up by pumice-stone and ash, and two islands of this matter, named Steers island and Calmeyer, appear above the water. As they are only a few meters high they will soon disappear owing to the force of the waves. The area over which the ashes fell down is estimated at the very least to be 750,000 square kilometers, an extent equal to Sweden and Norway. The finer particles of the ashes fell even beyond this area, as is shown by the log-books of sailing vessels and steamers, but the finest particles, saturated with a large quantity of vapour, have been floating for a long time in the upper strata of the atmosphere, and, propelled by the winds, travelled right round the world. The vapour ascending was condensed into water, and got frozen in the cold strata of the atmosphere, and the refraction through the numerous ice crystals produced the fine purple sunsets, which in the last months have been witnessed at several places in Asia, Africa, Europe, and America (no mention is made of Australia), while the particles of ash obscured the light of the sun or imparted blue and green colours to the sun when rising or setting. The enormous distance to which these ashes have been carried is proved by snowflakes that fell in Spain and rain that fell in the Netherlands, which were found to contain the very same component parts as the ash from

Krakatau. The height which these ashes attained at the time of the last terrific explosions was immense. A steam cloud, which rose from the crater on the 20th of May, at the time of the first eruption, was observed on board the German corvette 'Elizabeth' —which left Anjer on that day at nine o'clock in the morning— and had attained a height which was estimated at about 11,000 metres. As the explosions on the 26th and 27th of August were of a much grander nature, it is possible, should the above calculation be correct, that the ashes reached a height of 15 to 20 kilometers.

"A most remarkable phenomenon at the time of the eruption was the immense sea-waves which submerged the low-lying coasts of the Sunda Straits, and destroyed a large number of kampongs, resulting in the loss of the lives of 35,000 people. It is strange that the largest wave—the only one that ran along the north coast of Java and in the direction of the south-west at great distances, and was higher than all others—was hardly seen at any of the places. At Tjaringui alone the wave was observed before darkness set in, and that was about ten o'clock in the morning (?) of the 27th August. Anjer was destroyed at six o'clock in the morning, and deserted. This wave happening during the night little was seen of it. The gigantic wave which arose round Krakatau at about ten minutes to ten travelled over an immense area; for instance, to Ceylon, Aden, Mauritius, Port Elizabeth in South Africa, and even to the coast of France. As to the rapidity of the wave little is known, as it varies with the depth of the sea. When all the reports from the tide-gauges have been received, Mr. Verbeek will recur to this subject. However, the speed on its way to Mauritius and the Cape was enormous—namely, 500 minute miles per hour—a speed which equals that of the lunar tidal wave, and of the waves of the earthquakes of Simoda, in Japan, on the 23rd December, 1854, and of Tacna, in Peru, on the 13th of August, 1868.

"The height of the great wave of ten o'clock varied greatly at some places—Vlakke Hoek, 15 meters; south side of the island Dwars in den eveg, 35 meters; south side island Toppenhoedge, 30; north side, 24 meters; north of Anjer, opposite Brabandshoedge, 36 meters. The height varies with the situation of the places, the distance from Krakatau, and the nature of the coast.

"Extraordinary objects have been ejected during the eruptions —viz., very small, round, little bullets, resembling marbles, of a diameter of $1\frac{1}{2}$ to 6 centimeters. These bullets are found on the bottom of the Sunda Straits, in the vicinity of Krakatau, and were ejected through the crater."

ABSTRACT OF PROCEEDINGS OF SECTION A.

25th March.

High-speed Engines. Professor Kernot.

The minutes of the last meeting having been read and confirmed, Professor Kernot said he desired to place his resignation as chairman of the section in the hands of the members, as he did not think it either becoming or in order for one man to be President of the Society and chairman of one of its sections; and as the Society had honoured him by electing him to the Presidency—lately vacated by Mr. Ellery, amidst the regrets of all—he thought this a fitting opportunity to give place to a worthy successor.

There was a unanimous feeling among the members present that such a step would be detrimental to the best interests of the section, and Professor Kernot was urged to reconsider his determination. He promised to consider the matter most carefully, and seek the advice of Mr. Ellery, who, he was sure, would give such advice as would be wisest and best in the interest of the section and of the Society.

The ordinary business was then proceeded with. Two subjects were on the notice paper—

(1.) A review of the present state of machine development, under the title of "High-speed Engines," by Professor Kernot.

(2.) A paper by Mr. W. R. Rennick, on "Boiler Riveting." This latter was postponed till next meeting.

Professor Kernot, President of the Society, gave a brief outline of the development of the steam engine. The old engines, he said, were usually of large size, working at low velocity at low pressure, relying largely on the vacuum, and increasing the speed by means of pulleys and cogwheels. The general tendency of modern practice, on the contrary, is towards high speed direct-acting engines. Since the work done is the product of the force exerted into the distance over which it is exerted, it follows that the greater the speed at which a machine can work the less will be the stress on the parts and the lighter the parts can be made. At the present time two lines of investigation and experiment are being followed:—1. Single-acting engines represented by the Brotherhood, Westinghouse, and many other types. 2. Double-acting engines, represented typically by the Porter-Allen engine. The Westinghouse, the most modern of single-acting engines, has two cylinders, with cranks 180 deg. apart. The centre line of the cylinders runs clear of the shaft in such a way that on the steam stroke the connecting rod is nearly in the centre line. Thus little friction is caused in the cylinder by the obliquity of the connecting rod. On the return stroke, when no work is being done, the obliquity is considerable. Owing to this feature, again, there is mathematically no dead point, and practically there is none on account of the high speed. It is a proof of the remarkable performances of this engine that one has run for five months at a rate of 550 revolutions per minute, with only two stoppages of fifteen minutes each. The Porter-Allen engine is a slight modification of the older double-acting engines, and its chief feature is the great care bestowed on the balancing of its parts, the weight of which cannot be altered without diminishing the efficiency of the engine. Edison has largely employed these engines for working his dynamos, and one of them has been known to run for three months at 350 revolutions per minute without stopping. The chief contention of the advocates of the single-acting engines is that all their parts are in compression, and that the wear and noise must be at a minimum. This latter point does not seem to be realised in practice, owing probably to the inertia of the rapidly-moving parts. On the other hand, the supporters of the double-acting system aver that there are really only two parts which can suffer much from wear—viz., the pins of the connecting rod, and on the fitting of these they bestow great care, besides attending very carefully to the proportions and balancing of the moving parts. Their strong point is that double as much work can be got out of a double-acting as out of a single-acting engine. All things being considered, it seemed probable that it was to the double-acting system we must look for the best results in the future.

A short discussion followed the reading of the paper.

29th April, 1885.

The Secretary was unexpectedly detained, and was absent from the meeting. No detailed minutes were taken. Two subjects were on the notice paper—

(1.) Mr. Rennick's paper on "Boiler Riveting."

(2.) Mr. M'Lean, on "Long Shafting."

The whole evening was taken up by the first paper, and the discussion on it and the second paper had to be postponed to the next meeting.

27th May, 1885.

LONG SHAFTING. MR. C. W. M'LEAN, C.E.

SEWAGE SYSTEMS. MR. L. H. CHASE, C.E.

Professor Kernot explained that he had consulted with Mr. Ellery as to the question which was brought up at the March meeting of his retaining the chair of Section A.

Mr. Ellery's opinion was that, though as a general rule, it is not a good rule that one person should be President of the Society and Chairman of one of its sections, yet, in view of the strong feeling expressed by the members for Professor Kernot to retain the chair, he thought in this case it was permissible. Acting on this advice he would continue as chairman for the present, but he hoped to see some other member fill the place as soon as a fit opportunity should arise.

Three papers were before the meeting.

(1.) One by Mr. M'Lean, on "Long Shafting." Postponed from the last meeting.

(2.) One by Mr. G. R. B. Steane, on "Rainfall and Flood Discharge."

Mr. Steane was absent, on account of a death in his family, and asked that his paper might be postponed. This was accordingly done.

(3.) Mr. L. H. Chase, on "Sewage Systems."

The first paper read was Mr. C. W. M'Lean's, on "Long Shafting."

The operation of ranging long lines of shafting is usually effected by means of a piano wire about 100 feet long, strained tight. But this method is open to one great disadvantage—the sag. Taking resistance to tearing at 100,000 lbs. per square inch, and weight equal to ·26 lbs. per cubic inch, we can see that if this could be strained up to the point of rupture without yielding, the sag would be about ½ inch. The operator estimates the true line, and places the bearings accordingly. Of course this method, with ordinary care, will give the horizontal direction close enough. The importance of having the line very accurate would seem to be great, for it is invariably found that in carelessly-laid work either the shaft heats or else the couplings or the crank break. The first departure from this practice seems to have been the use of a disc and tube, though this is not perfect on account of the obstruction of light at the slit in the tube. A short time ago Mr. M'Lean was called on to examine some long shafting, which was working very badly; and to do this more perfectly than could be done by the old system, he devised the following method:—

In the case under notice the couplings were all of one size, but a similar method could be applied in any case. He placed a telescope having crosswires on one of the end couplings, and held it in place by a small block of wood as a carrier, and a weighted string passing over the whole. A small scale was then placed vertically on the other end coupling, and the reading taken, and the process repeated at each intermediate coupling piece. The comparison of the results showed an error of about ¼ in. at one end. The soleplate was planed down by this amount, the shafting readjusted, and the result has been perfectly satisfactory.

Probably the best method would be to use a mining telescope, and set up at some little distance from the end coupling. A stand, to carry the telescope and rest on a flat, convex, or concave surface, is easily made by taking two boomerang-shaped supports, with convexity downwards. The whole work can be done with the telescope in less time than it takes to set up the wire in the old method. In the discussion which followed, Professor Kernot said he saw no reason why there should be any difficulty in working a shaft 100 feet long, sprung one foot at the centre, and instanced Hereschoff's torpedo, where the shaft is warped about a foot.

Against this view it was remarked that the usual interval for 12-in. shafting is 12 feet, and that in this case the alignment becomes a very important factor. The modern practice is to have overhung screws (rather than, with an outside bearing), and to support the shafting at many points very carefully laid.

Mr. Chase then read his paper on Sewage Systems.

The question of sewage is all-important in its bearing on the health of a large city. Four systems of sewage disposal have come into pretty general use.

(1.) To run the sewage matter direct into a river or the sea. This is a fairly good method if the tide will carry the matter away to sea, but not otherwise. This is the Melbourne method, and here we have no tide to speak of.

(2.) Precipitation by lime or other chemicals.

(3.) Intermittent filtration through land with irrigation.

(4.) Precipitation and intermittent filtration or irrigation. This is the best method when the natural drain of a country is a clear stream of no great size.

Closely connected with the question of sewage is the disposal of town refuse. At Blackburn, with a population of 100,000, the rubbish is burnt in destructors. These are large inclined grates in brick chambers, and have furnace doors in front. With careful stoking it is found that the rubbish will consume itself. The chimney is tall, and no nuisance arises from it. The clinkers are used for foundations of roads.

Part of the sewerage is simply precipitated with lime. Strong lime-water is mixed with the sewage in settling ponds, *i.e.*, drains about 12 feet in width. The solid matter settles to the bottom and is pumped off as a sludge, and kept under cover till solid enough to be dug out, when it is carted away as manure.

At Burnley, with a population of 60,000, the works are situated near a small stream. The method of treatment is Scott's Patent. It seems to give excellent results, but the expense of the system leaves small margin for payable results. The following is a brief description of the method :—The sewage enters at one corner of the works, passing through a screen or grating, so as to stop all large refuse. It runs down the lime race, meeting a series of interlaced boards along the whole length. Lime-water, containing one ton of lime per million gallons, is poured in by the engine just below the screen. At the end of the race are the settling ponds, which consist of two portions, used alternately, each taking about a fortnight to fill with sludge. When one pond is full the flow is turned into the other, and the sludge is pumped into the filters. These are enclosures of brick, about 4 feet in height, 6 feet wide, and 20 feet long. The floor is covered with a layer of coke. In these the water is allowed to drain off till the sludge can be dug out. The white sludge is now spread on an iron drying floor to a depth of about one foot, and dried by fire. The result is a layer of about 4 inches of white cracked material, about the size of half bricks. These are burned in kilns, with a little fuel (themselves supplying most of it), and the product of this process is ground in a Chilian mill, and called Portland cement. Its tenacity is about 300 lbs. per square inch. The water from the settling ponds runs over a shoot into the river. Beside this one is a second shoot for testing the purity of the water. It is lined with glazed white bricks. To test the colour, about 4 inches of water is run over the test shoot; the inspector should see no perceptible colour. Even then, however, it might not be amiss to subject the water to a careful chemical and microscopical examination at times, in order to ensure purity. When sewage comes to the works with more than a certain proportion of water it is allowed to flow direct into the river.

Perhaps the most elaborate sewage works are those at Salford, Manchester. The profits, however, seem to be very small, if any. At this place closet pans are in use, which are emptied into airtight carts, in which they are carried to the works. The nightsoil is there deposited in large iron cylinders. These are heated by steam, and the contents dried into manure. The steam for this purpose is generated in boilers, of which the fuel is part of the town refuse from the dust carts. The rest of the rubbish is treated with sulphuric acid, and gives a good manure. The nightsoil manure is worth £3 per ton. At times loads of condemned fish are brought to the works. The oil is extracted from them, and the residue is manure worth £9 per ton. The oil and such grease as comes from other sources is made into soap and candles.

At some works near the last the system is not nearly so elaborate. The nightsoil is discharged into a large reservoir, the rubbish sifted in an inclined cylinder. The ashes are thrown in among the soil of the larger pieces burnt in destructors. The nightsoil is then taken up the canal in large barges as manure, and the cost of removal is paid by the sale of the soil.

One more interesting case claims our notice. Part of the fashionable seaside town of Eastbourne lies below the high water mark, and at times a high tide would force back the sewage in the drains. This difficulty was very successfully met by means of the Shore system. An air compressor was erected $1\frac{1}{2}$ miles inland, and compressed air at about 10 lbs. pressure is carried to the town in pipes opening into two large tanks. When the tide is high the sewers discharge into one of two large receivers sunk in the beach. When this one is full a valve is opened, and air comes in, forcing the matter out to sea. The set of the current is such as to carry all the matter out to sea, leaving the beach clean.

It is much to be desired that we may ere long see some such method as has been described in use in Melbourne. Surely no justification can be found for such wilful pollution of one of the finest streams in the colony as is carried on at the present time.

June 24th, 1885.

RAINFALL AND FLOOD DISCHARGE. MR. G. R. B. STEANE, C.E.

There was a small attendance at this meeting, owing to the inclement weather.

Discussion on Mr. Steane's paper was postponed to the next meeting.

Mr. C. W. M'Lean exhibited a very novel instrument known as the "Metacentre Balance." This was also shown later on at an ordinary meeting of the Society, so there is scarcely any need of further description in this place.

The present state of the science of hydrology is very unsatisfactory indeed. Authorities differ as to whether we should call the maximum rainfall $\frac{1}{2}$ inch or 1 inch per hour. It is not difficult to make the dimensions of waterway excessive; the great problem is to make them just sufficient, no more and no less. Merely to gauge a stream with a view to constructing permanent works is very unsatisfactory, for improved drainage may entirely change the aspect of the question, giving rise to the need of large waterway. A careful study must be made of the rainfall of the district under notice—of the nature of surface and inclination of the channel. Thus, sandy loam and chalky ground act very differently. The rate of discharge will increase with the rainfall, the area (within certain limits), the slope of the ground, and improved drainage. It will decrease with the increase of reservoirs and the porosity of the ground, and also as the ratio of the length to width of the drainage area increases.

It is worthy of notice that a rainfall of 1 inch per hour over one acre is equivalent to about 1 cubic foot per second.

We must carefully distinguish between the cases of large and small areas. Very heavy rains seldom last more than a few minutes, and hence, though in a small watershed they might cause comparatively heavy floods, yet in a large area their effect might be quite inappreciable, for it is known that the very heavy rains, such as 1 inch per hour, are extremely local. Such rains, also, are short in duration, and the quantity which falls increases very slowly with the time.

The law of increase is approximately represented by the formula $F = k\,T^{\frac{1}{3}}$ where F = fall, t = time, the areas and times being supposed small.

Hence the rate of fall, $R = \frac{F}{T} = k.T^{-\frac{2}{3}}$

Now let us consider a watershed of constant narrow width, and let us assume that the water flows at a constant velocity down the channel.

Then the length drained will vary as the time

$i.e., L \propto T$

but $D = R \times A = R \times L \times C$

$i.e., D \propto R.L$ ——— (2)

Hence by (1) $D \propto \frac{L}{T^{\frac{2}{3}}}$ ——— (*a*)

Corresponding with the formula given by L. D'a Jackson. Ed. 1883.

But in practice none of the premises are correct.

Hence we should amend the formula to the form

$$D = h.\frac{L}{T^{\frac{2}{3}} \pm p}$$

where p is some variable depending on soil, &c., but constant for any given watershed.

In most watersheds the slope of the ground is such as will tend to equalise the velocity over the whole length, so that we are led to the conclusion that the best simple formula is of the form

$$D = C.\frac{K}{L^{x} \pm a}$$

a parabolic curve, though not a common parabola.

From a careful study of the Bendigo Creek, the following data resulted.

D = 4100 cubic feet per sec.
K = 10,000 acres
L = $7\frac{1}{2}$ m.

The Coliban gave

D = 10,000 cubic feet per sec.
K = 100 square miles

And another small area gave

D = 4 cubic feet per sec.
K = 4 acres
L = 7 chains

Hence Mr. Steane deduces the formula

$$D = \frac{\text{Area in sq. chains} \times 181}{(\text{length in chains})^{1\cdot 23} + 1800}$$

This has given good results in nearly all cases by which it was tested after construction, as is shown by the following table:—

LOCALITY.	DISCHARGE.		REMARKS.
	ACTUAL.	BY FORMULA.	
	Cubic feet per sec.	Cubic feet per sec.	
Flinders Street Drain	410	430	
Reilly Street Drain...	1,118	1,342	
Axe Creek, at Harrow	4,970	4,540	Doubtful
" " Axedale	13,827	11,820	"
Campaspe	54,000	34,600	Approx. dimension only
Yarra (flood of 1863)	35,000	36,700	

It may be worth while to notice what rainfalls have given rise to large floods.

The largest-known flood at Sandhurst occurred in April, 1878. The rainfall in Sandhurst was ·63 inches, and at Crusoe Reservoir 1·91 inches in one hour.

The drainage area is 10,000 acres. If 1·91 inches had fallen over the whole area at the same time, the flood would have been three times as great as the largest known.

The next largest was during the heaviest twenty-fours' rain, during which time 3·67 inches was recorded at the Survey Office, and 4·72 inches at the Crusoe Reservoir, so that this rain was evenly distributed over the district. The maximum fall in one hour during this rain was ·46 inches, and during two hours ·76 inches, and the discharge was only three-quarters of that on the former occasion.

The following formulæ are given by some writers for the discharge of channel pipes in cities:—

$$D'' = 4\cdot 786\, A^{\frac{3}{10}}\, L^{\frac{1}{10}}$$

or else, which is more recent,

$$D = r\cdot c \sqrt[4]{\frac{i}{a}}$$

in which $c = \cdot 75$ for dense cities

$= \cdot 31$ for suburbs, with gardens, &c.

$r =$ average rainfall

$i =$ slope

This formula will not hold in all cases; for example, if

$$a=\tfrac{1}{4}\text{-acre}$$
$$i=\tfrac{8}{1000}$$
$$r=3 \text{ in. per hour}$$

(so that D must be less than $\frac{3}{4}$ cubic feet per sec.) the formula gives

$$D=3\times\cdot 75\sqrt[4]{\frac{8}{\frac{1}{4}}}=5\cdot 3 \text{ cubic feet per sec.,}$$

and this result is obviously false.

It will thus be seen in how very unsatisfactory a state is this branch of engineering. Some attention should certainly be paid to it, and one may safely say that in a few years we shall be in a better position than at the present time.

30th September, 1885.

THE COOTAMUNDRA RAILWAY DISASTER. Professor KERNOT.

The details of this fearful disaster are fresh in the memory of all our members. A heavy flood washed away a portion of the railway embankment near Cootamundra, N.S.W., and a train dashed at full speed into the chasm. Many people were killed, and more injured.—25th January, 1885.

His acquaintance with the site was formed during two journeys in a slow train shortly after the accident. Cootamundra is about half-way between Wodonga and Sydney. It is situated in the Murrumbidgee watershed. The Dividing Range is crossed about 100 miles further on towards Sydney, so that Cootamundra is not on the rainy-coast watershed, but is characterised by a climate more like that of Victoria. The portion of the bank which was washed away is at the crossing of the Soft Clay Creek. This creek is a tributary of the Murrumbidgee, and flows through country very much like that about the Yarra at Kew. The line crosses the creek by three culverts—(1) an 8-ft. barrel drain, equal to 52 square feet; (2) apparently the same; (3) a brick barrel drain, having about 200 square feet of waterway. The country is lightly timbered, and the formation is hard rock to the surface, apparently stratified. There was heavy rain on the 24th January, and a small breach was formed at the third culvert; another was formed at the second, and the accident took place at the first. The catchment area is variously stated at from 20 to 30 square miles. Mr. Whitton says 13,000 acres.

For the defence Mr. Morell, of the New South Wales Railway Department, stated that one-third of the area was not very absorbent, and that the rest consists of flats and uncleared ground.

It was further urged that the culverts were correctly designed for ordinary floods; but that in this case the bursting of several dams above the embankment caused an exceptionally heavy flood. The jury unanimously decided that the culvert was large enough to carry all previous rainfall.

As to the question of the bursting of the dams, Mr. Morell estimated the flood water from the dam at 235,000 cubic feet. Mr. Simson stated there were dams holding respectively 1,047,000, 631,000, and 130,000 cubic feet. These must, however, have been some distance away, as those visible from the railway are only small ones, like cattle dams. Mr. Russell, of the Sydney Observatory, stated that in some cases the discharge is only about 1 per cent. of the rainfall. Mr. Whitton stated that he had decided the sizes of all the culverts on the railway, including the Cootamundra culverts. He further stated that there was a head of 12 feet of water to force the water through the culverts.

Against this statement Professor Kernot raised the objection that a railway bank should not be made to act as a dam, for no care is taken to render it impervious to water. As to the rainfall on the day of the accident, Mr. Matthews stated that 4·00 inches fell during the day of the accident and 4·97 on the 24th; and there is a record showing 3·08 of rain on the day of the accident 40 miles to the west, so that the heavy rain would seem to have been very general.

Professor Kernot's conclusion is that the bursting of the dams was but a small matter in comparison with the natural flood discharge, and that the size of the first and second culverts was quite inadequate; but as a new channel was cut so as to divert the stream from these two, recurrence of the accident will probably be prevented.

In the discussion which followed, Mr. Steane gave some further details collected from the evidence.

Mr. Morell stated that the waterway of the culvert where the bank failed was 52·78 square feet; that the velocity of the water through this culvert, with a heading of one foot above the crown, would be 17·6 feet per second. Further, that as the catchment area was 21 square miles and the absorption probably 70 per cent. of rainfall, this culvert would discharge 28-in. fall per hour.

Mr. Steane gave as an analogous case the Bendigo Creek, at Sandhurst. The bridge was originally of 5 bays, with waterway of 190 square feet, for catchment of 10,000 ac., the basin being mostly impervious. This caused frequent floods, of from 4 feet to 5 feet, with such rainfalls as ·63 inch per hour, as mentioned in his paper on "Rainfall and Flood Discharge." Mr. Steane took the dimensions carefully, and came to the conclusion that the Bendigo Creek culvert would not discharge more than 4100 cubic feet per second. He made a new culvert of 370 square feet waterway, and put an end to further floods.

The effect of a heavy rainfall on the catchment should be noticed. The first effect is to soak the ground. The ultimate absorption is greater in summer than in winter, but averages about ·08 inch per hour in the Bendigo Creek country, or say 1-10th inch per hour. Mr. Steane found that with a heavy downpour, after steady rain, took one hour and fifty minutes for rain at the end of the catchment to reach the mouth, so that to get a maximum flood we must have two hours' rainfall. If the rain lasted two hours, we should get a maximum, and then flood would fall; but if it lasted three hours, we should get maximum, stay there for one hour, and then fall.

The dimensions of the culverts on the Cootamundra line do not seem to have been fixed with regard to catchment areas at all. There is one of 8 feet at Albury for a catchment of 1 square mile, and in most cases the sizes are excessive.

25th November, 1885.

A paper was read by the SECRETARY on Mr. Claxton Fidler's graphic method of computing the stresses on continuous girders.

The method is merely a graphical expression of the equation of three moments, and was not new to any of the members present. At the conclusion of the paper there was a discussion on the use of continuous girders.

Mr. BEHRENDT pointed out that the English engineers are far behind the Germans in many matters, and particularly in this question of continuity. Twenty years ago a German engineer—Gerber—had solved the difficulty by using overhung girders carrying a central girder between them.

Professor KERNOT remarked that, quite independently of Gerber, Mr. T. W. Fowler had suggested an almost identical arrangement at the meetings of section A. It was also remarked that the American engineers now invariably avoid the use of continuous girders.

Mr. John Booth read a paper on "Systems of Electric Lighting."

A system consists of three essential parts—

1. A dynamo.
2. A lamp.
3. Conducting wires.

Considering, first, the simple incandescent lamp system. In this case we have an electro-motive force, E in the dynamo falling through a resistance R in the dynamo itself, r in the wires, and S in the lamp, thus the current $C = \frac{E}{R + r + r'}$

This transforms $\frac{E^2}{R + r + r'}$ Watts from horse-power into heat (since there is no mechanical movement in the outer circuit), and since this is distributed according to Joules' Law $H = \frac{R\, c^2\, t}{J}$ it is evident that we must make the resistance of the lamp high compared with that of the rest of the circuit.

Let us now consider what is done in practice.

There are two distinct methods of treating the case, known as the series and the parallel arrangements. In the former we pass the same current through lamp after lamp, and in the second, increasing the current in proportion to the number of lamps, we divide it up between the various lamps of the system.

All other methods are modifications or combinations with slight modifications of these two great systems.

To bring before our mind more clearly the points of resemblance and of difference of these two systems, we may examine the following case :—

And first take the SERIES SYSTEM.

Suppose we are dealing with 100 50-volt lamps, taking 1 ampere of current and developing 16 candle power, we shall require an E.M.F. at least equal to 5000 volts—a tension that is approaching the dangerous—and even then only 100 lamps are supplied. If we calculate on a 90 per cent. efficiency we have $R + V = 500$ ohms. This would mean an inexpensive dynamo of small size, and, supposing the lights to be one mile away, a No. 28 main wire (·34 mm.)

But another difficulty is, that the failure of one lamp of the series interrupts the circuit and puts all the others out.

This is not likely to occur in arc lamps, and they are almost always worked in this way; but an incandescent lamp may fail at any minute, and hence we shall have to find some method of providing against this contingency. With such a high E.M.F., too-switching is almost impossible, and a special arrangement must be introduced in the dynamo itself.

The pure series system, then, will not be troubled with the problem of keeping down the resistance of the dynamo and line, but will, without any difficulty, have nearly all the energy reproduced in the lamp. But it will require to be provided with the most perfect insulation and safety arrangements, and some special apparatus for providing against failure of the lamp and with the requisite quantity of current.

We must next consider the *parallel system.* Suppose, as before, we have 100 fifty-volt lamps, then we shall require a current of

100 amperes. Our lamp resistance will thus be $\frac{50}{100} = \frac{1}{2}$ ohm; and assuming again a 90 per cent. efficiency, we shall have to make $R + r = \frac{1}{20}$ ohm, which means a very expensive machine of very heavy wire, and if the lamps are as before—one mile away—our conducting wire must be of 16-in. diameter, and pure copper.

The E.M.F. required will be a trifle over 50 volts—a very low tension, the shock of which can hardly be felt, and the spark at breaking of contact will be very slight. The points against the parallel system are either the expense of the machine and wire on the one hand, or the inefficiency if the cost of the machine, &c., is kept down.

In its favour it may be said that it is free from danger, and that one lamp going out hardly affects the rest. This includes the important consideration that any lamp can be turned on and off at pleasure. This is the mode usually adopted, and is the only one that has been practised in Melbourne, a compromise being effected between the cost of the machine and its efficiency. As we have seen above, all the other systems in use must depend on application of these two. A brief reference to two or three of the more important of them must now be made.

There are two methods which are so closely allied to the fundamental systems that they must be taken next in order. These are the *series-multiple* and the *multiple-series* systems.

In the one the main current traverses two large main-wires, and these are tapped at intervals by secondary wires, each of which carries a series of lamps. Of course the failure of a single lamp in the series puts that group out, but does not affect any of the other groups appreciably. In the second we have one main wire carrying groups of lamps at various points (the current, of course, being divided at each point, passing through the lamps, and then converging once more into the main wire, and so on for each group).

The advantages are lighter mains, and consequently a larger range, while the disadvantages are the danger, and that a whole group must go out at one time. Thus we shall need group cut-outs, lamp cut-outs, and a current regulator.

The groups need not be identical, but must each take the same amount of current. In using the series-multiple system we can provide against the failure of any one lamp by means of an idle wire passing from group to group—of course so long as the potential at each end of this wire is the same, no current passes along it, but as soon as it is altered at one end—as by a lamp going out—the whole current for that group passes along it. Of course it is possible to extend the idle wire to the machines, bringing it in between the two. We are not aware that much has been done in this way yet, but it seems to be a promising field. By using it any part of the whole column may be extinguished. Of course the extra copper required for the idle wire is above that in the series-multiple, but the total quantity is considerably less than would be required in parallel series.

The greatest objection seems to be the difficulty of attending to the management of two or more dynamos in parallel series.

There is another method in use, which is closely connected with the above systems, though hardly deserving the name of separate systems. It is known as the high resistance system. It has been attempted to get greater efficiency by increasing the resistance of the lamp, so that it may have a high ratio compared with that of the dynamo and line. Probably the highest resistance is attained in the Edison lamp, a hundred volt lamp. The limit to resistance is the difficulty of manufacture, and the fact that the filaments are not very durable under current.

Secondary Systems.—In all the foregoing the actual current generated by the dynamo is utilised in heating the lamp. But in the secondary systems the main current is not so employed, but passes into more mechanism, which, in its turn, supplies the lamps with current.

The principal of these are the *motor* and the *secondary generator* systems. The secondary mechanism employed in the latter is similar to the Rhumkorff induction coil. The most convenient form of current conveying the requisite amount of energy is transmitted through the mains, and passes into the secondary generator as a primary circuit, and the secondary current is modified to the purpose required by the winding or joining up of the secondary wire. The main current is of high E.M.F. to avoid heavy conductors, and must be of the "alternating current" class.

This system has all the disadvantages of the series system in danger and difficulty of control; but as it has only to pass into the secondary generator, and not into the dwelling-houses, the danger is to a great extent obviated, and all the controlling required is done in the secondary circuit.

But besides these two we have another very important branch, which, though it can hardly be classed as a separate system, yet may be so important a factor in any other system as to give it a distinctive name. This is the *secondary battery.* In this method the electrical energy carried by the current, instead of passing directly into the lamps, is sent through a suitable arrangement, and, instead of being reproduced as heat, the energy is expended in altering the molecular condition of the plates and liquids in the battery, so as to form a store of chemical potential energy, which can be for a time retained in that form, and subsequently, by completing the circuit, be allowed to flow out in any form of current that may be desired. Thus a high-tension current may be employed for charging a secondary battery at a distance, and the battery may afterwards be used to supply current to a set of lamps in parallel series.

The usual method of using the secondary battery is to arrange for a constant supply of current less than is required for the total power of the lamps to be supplied, but more than the minimum power used. When a small number of lamps are lit, the balance of current from the dynamo goes to charge the battery which will be used conjointly with the dynamo when the full power is required for the lamps.

The only serious objection to the secondary battery is an obvious one—its leakiness—and this cannot well be provided against.

Such are the main points to be considered and difficulties to be overcome in designing a system of electric lighting. And from what has been said it can readily be understood there is very wide room for improvement, even in the broadest outlines. But, even after having chosen the particular system to be used, there is still an almost infinite number of details to be considered, all of them important, and no one of which can be overlooked. We have only to mention a few of these to bring this conclusion very forcibly home to your minds—the dynamo, with its general outline, style of winding, speed, class of armature, commutator, terminals and fittings, lubricators, ventilators, &c. But after all these have been satisfactorily arranged, we must face all the difficulties of the mains, switches and branches, the lamps and holders, the safety-fuse, the carriage and insulation of the mains, the main and branch junction boxes, the magnetic cut-outs, the regulators of potential and current, and the testing arrangements.

It is the blending of all these into one harmonious whole, every contingency being foreseen and having its pre-arranged remedy, and where necessary its appropriate piece of mechanism, that constitutes an electric system.

LAWS.

Name. I. The Society shall be called "The Royal Society of Victoria."

Objects. II. The Royal Society of Victoria is founded for the advancement of science, literature, and art, with especial reference to the development of the resources of the country.

Members and Honorary Members. III. The Royal Society of Victoria shall consist of Members and Honorary Members, Corresponding Members and Associates, all of whom shall be elected by ballot.

Patron. IV. His Excellency the Governor of Victoria for the time being shall be requested to be the Patron of the Society.

Officers. V. There shall be a President, and two Vice-Presidents, who, with twelve other Members, and the following Honorary Officers, viz., Treasurer, Librarian, and two Secretaries of the Society, shall constitute the Council.

Management. VI. The Council shall have the management of the affairs of the Society.

Ordinary Meetings. VII. The Ordinary Meetings of the Society shall be held once in every month during the Session, from March to December inclusive, on days fixed by and subject to alteration by the Council with due notice.

Annual General Meetings. VIII. In the second week in March there shall be a General Meeting, to receive the report of the Council and elect the Officers of the Society for the ensuing year.

Retirement of Officers. IX. All Office-bearers and Members of Council, except the six junior or last elected ordinary Members, shall retire from office annually at the General Meeting in March. The names of such Retiring Officers are to be announced at the Ordinary Meetings in November and December. The Officers and Members of Council so retiring shall be eligible for the same or any other office then vacant.

Election of Officers. X. The President, Vice-Presidents, Treasurer, Secretaries, and Librarian shall be separately elected by ballot (should such be demanded), in the above-named order, and the six vacancies in the Council shall then be filled up together by ballot at the General Meeting in March. Those members only shall be eligible for any office who have been proposed and seconded at the Ordinary Meeting in December, or by letter addressed to one of the Secretaries, and received by him before the 1st March, to be laid before the Council Meeting next before the Annual Meeting in March. The nomination to any one office shall be held a nomination to any office the election to which is to be subsequently held. No ballot shall take place at any meeting unless ten members be present.

XI. No Member whose subscription is in arrear shall take part in the election of Officers or other business of the meeting. Members in arrear.

XII. An Address shall be delivered by the President of the Society at either a Dinner, Conversazione, or extra meeting of the Society, as the Council for the time being may determine, not later than the Ordinary Meeting in June in each year. Inaugural address by the President.

XIII. If any vacancy occur among the Officers, notice thereof shall be inserted in the summons for the next meeting of the Society, and the vacancy shall be then filled up by ballot. Vacancies.

XIV. The President shall take the chair at all meetings of the Society and of the Council, and shall regulate and keep order in all their proceedings; he shall state questions and propositions to the meeting, and report the result of ballots, and carry into effect the regulations of the Society. In the absence of the President the chair shall be taken by one of the Vice-Presidents, Treasurer, or ordinary Member of Council, in order of seniority. Duties of President.

XV. The Treasurer may, immediately after his election, appoint a Collector (to act during pleasure), subject to the approval of the Council at its next meeting. The duty of the Collector shall be to issue the Treasurer's notices and collect subscriptions. The Treasurer shall receive all moneys paid to the Society, and shall deposit the same before the end of each month in the bank approved by the Council, to the Duties of Treasurer.

credit of an account opened in the name of the Royal Society of Victoria. The Treasurer shall make all payments ordered by the Council on receiving a written authority from the chairman of the meeting. All cheques shall be signed by himself, and countersigned by one of the Secretaries. No payments shall be made except by cheque, and on the authority of the Council. He shall keep a detailed account of all receipts and expenditure, present a report of the same at each Council Meeting, and prepare a balance-sheet to be laid before the Council, and included in its Annual Report. He shall also produce his books whenever called on by the Council.

Duties of Secretaries.

XVI. The Secretaries shall share their duties as they may find most convenient. One or other of them shall conduct the correspondence of the Society and of the Council, attend all meetings of the Society and of the Council, take minutes of their proceedings, and enter them in the proper books. He shall inscribe the names and addresses of all Members in a book to be kept for that purpose, from which no name shall be erased except by order of the Council. He shall issue notices of all meetings of the Society and of the Council, and shall have the custody of all papers of the Society, and, under the direction of the Council, superintend the printing of the Transactions of the Society.

Meetings of Council.

XVII. The Council shall meet on any day within one week before every Ordinary Meeting of the Society. Notice of such meeting shall be sent to every Member at least two days previously. No business shall be transacted at any meeting of the Council unless five Members be present. Any Member of Council absenting himself from three consecutive meetings of Council, without satisfactory explanation in writing, shall be considered to have vacated his office, and the election of a Member to fill his place shall be proceeded with at the next Ordinary Meeting of Members, in accordance with Law XIII.

Quorum.

Special Meetings of Council.

XVIII. One of the Secretaries shall call a Special Meeting of Council on the authority of the President or of three Members of the Council. The notice of such meeting shall specify the object for which it is called, and no other business shall be entertained.

XIX. The Council shall call a Special Meeting of the Society, on receiving a requisition in writing signed by twenty-four Members of the Society specifying the purpose for which the meeting is required, or upon a resolution of its own. No other business shall be entertained at such meeting. Notice of such meeting, and the purpose for which it is summoned, shall be sent to every Member at least ten days before the meeting. Special General Meetings.

XX. The Council shall annually prepare a Report of the Proceedings of the Society during the past year, embodying the balance-sheet, duly audited by two Auditors, to be appointed for the year, at the Ordinary Meeting in December, exhibiting a statement of the present position of the Society. This Report shall be laid before the Society at the Annual Meeting in March. No paper shall be read at that meeting. Annual Report.

XXI. If it shall come to the knowledge of the Council that the conduct of an Officer or a Member is injurious to the interest of the Society, and if two-thirds of the Council present shall be satisfied, after opportunity of defence has been afforded to him, that such is the case, it may call upon him to resign, and shall have the power to expel him from the Society, or remove him from any office therein at its discretion. In every case all proceedings shall be entered upon the minutes. Expulsion of Members.

XXII. Every candidate for election as Member or as Associate shall be proposed and seconded by Members of the Society. The name, the address, and the occupation of every candidate, with the names of his proposer and of his seconder, shall be communicated in writing to one of the Secretaries, and shall be read at a meeting of Council, and also at the following meeting of the Society, and the ballot shall take place at the next following Ordinary Meeting of the Society. The assent of at least five-sixths of the number voting shall be requisite for the admission of a candidate. Election of Members and Associates.

XXIII. Every new Member or Associate shall receive due notice of his election, and be supplied with Members shall sign Laws.

a copy of the obligation,* together with a copy of the Laws of the Society. He shall not be entitled to enjoy any privilege of the Society, nor shall his name be printed in the List of Members, until he shall have paid his admission fee and first annual subscription, and have returned to the Secretaries the obligation signed by himself. He shall at the first meeting of the Society at which he is present sign a duplicate of the obligation in the Statute Book of the Society, after which he shall be introduced to the Society by the Chairman. No Member or Associate shall be at liberty to withdraw from the Society without previously giving notice in writing to one of the Secretaries of his intention to withdraw, and returning all books or other property of the Society in his possession. Members and Associates will be considered liable for the payment of all subscriptions due from them up to the date at which they give written notice of their intention to withdraw from the Society.

Conditions of Resignation.

Honorary Members.

XXIV. Gentlemen not resident in Victoria, who are distinguished for their attainments in science, literature, or art, may be proposed for election as Honorary Members, on the recommendation of an absolute majority of the Council. The election shall be conducted in the same manner as that of ordinary Members, but nine-tenths of the votes must be in favour of the candidate.

Subscriptions.

XXV. Members of the Society, resident in Melbourne, or within ten miles thereof, shall pay two guineas annually, Members residing beyond that distance and Associates shall pay one guinea annually. The subscriptions shall be due on the 1st of January in every year. At the commencement of each year there shall be hung up in the Hall of the Society a

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* The obligation referred to is as follows :—

ROYAL SOCIETY OF VICTORIA.

I, the undersigned, do hereby engage that I will endeavour to promote the interests and welfare of the Royal Society of Victoria, and to observe its laws, as long as I shall remain a Member or Associate thereof.

(Signed)

Address

Date

list of Members and Associates, upon which the payments of their subscriptions as made by Members and Associates shall be entered. During July notice shall be sent to Members and Associates still in arrears. At the end of each year a list of those who have not paid their subscriptions shall be prepared, to be considered and dealt with by the Council.

XXVI. Newly elected Members shall pay an entrance fee of two guineas, in addition to the subscription for the current year. Newly elected Associates shall not be required to pay any entrance fee. Those elected after the 1st of July shall pay only half of the subscription for the current year. If the entrance fee and subscription be not paid within one month of the notification of election, a second notice shall be sent, and if payment be not made within one month from the second notice, the election shall be void. Members resident in Melbourne, or within ten miles thereof, may compound for all Annual Subscriptions of the current and future years by paying £21; and Members residing beyond that distance may compound in like manner by paying £10 10s. Associates on seeking election as Members shall have to comply with all the forms requisite for the election of Members, and shall pay an entrance fee of two guineas.

Entrance fees, &c.

Life Membership.

XXVII. At the Ordinary Meetings of the Society the chair shall be taken punctually at eight o'clock, and no new business shall be taken after ten o'clock.

Durations of Meetings.

XXVIII. At the Ordinary Meetings business shall be transacted in the following order, unless it be specially decided otherwise by the Chairman:—

Order and mode of conducting the business.

Minutes of the preceding meeting to be read, amended if incorrect, and confirmed.
New Members to enroll their names, and be introduced.
Ballot for the election of new Members.
Vacancies among officers, if any, to be filled up.
Business arising out of the minutes.
Communications from the Council.
Presents to be laid on the table, and acknowledged.
Motions, of which notice has been given, to be considered.

Notices of motion for the next meeting to be given in and read by one of the Secretaries.

Papers to be read.

Strangers.

XXIX. No stranger shall speak at a meeting of the Society unless specially invited to do so by the Chairman.

What business may be transacted.

XXX. At no meeting shall a paper be read, or business entertained, which has not been previously notified to the Council.

Additional Meetings.

XXXI. The Council may call additional meetings whenever it may be deemed necessary.

Visitors.

XXXII. Every Member may introduce two visitors to the meetings of the Society by orders signed by himself.

Members may read papers.

XXXIII. Members and Associates shall have the privilege of reading before the Society accounts of experiments, observations, and researches conducted by themselves, or original papers, on subjects within the scope of the Society, or descriptions of recent discoveries, or inventions of general scientific interest. No vote of thanks to any Member or Associate for his paper shall be proposed.

Or depute other Members.

XXXIV. If a Member or Associate be unable to attend for the purpose of reading his paper, he may delegate to any Member of the Society the reading thereof, and his right of reply.

Members must give notice of their papers.

XXXV. Any Member or Associate desirous of reading a paper shall give in writing to one of the Secretaries, ten days before the meeting at which he desires it to be read, its title and the time its reading will occupy.

Papers by strangers.

XXXVI. The Council may permit a paper such as described in Law XXXIII., not written by a Member of the Society, to be read, if for any special reason it shall be deemed desirable.

Papers belong to the Society.

XXXVII. Every paper read before the Society shall be the property thereof, and immediately after it has been read shall be delivered to one of the Secretaries, and shall remain in his custody.

Papers must be original.

XXXVIII. No paper shall be read before the Society or published in the Transactions unless approved by the Council, and unless it consist mainly of original matter as regards the facts or the theories enunciated.

XXXIX. Should the Council feel a difficulty in deciding on the publication of a paper, the Council may refer it to any Member or Members of the Society, who shall report upon it. Council may refer papers to Members.

XL. Should the Council decide not to publish a paper, it shall be at once returned to the author. Rejected papers to be returned.

XLI. The author of any paper which the Council has decided to publish in the Transactions may have any number of copies of his paper on giving notice of his wish in writing to one of the Secretaries, and on paying the extra cost of such copies. Members may have copies of their papers.

XLII. Every Member and Associate whose subscription is not in arrear, and every Honorary Member, is entitled to receive one copy of the Transactions of the Society as published. Newly elected Members shall, on payment of their entrance fee and subscription, receive a copy of the volume of the Transactions last published. Members to have copies of Transactions.

XLIII. Every book, pamphlet, model, plan, drawing, specimen, preparation, or collection presented to or purchased by the Society shall be kept in the house of the Society. Property.

XLIV. The Library shall be open to Members and Associates of the Society and the public at such times and under such regulations as the Council may deem fit. Library.

XLV. The legal ownership of the property of the Society is vested in the President, the Vice-Presidents, and the Treasurer for the time being, in trust for the use of the Society; but the Council shall have full control over the expenditure of the funds and management of the property of the Society. Legal ownership of property.

XLVI. Every Committee appointed by the Society shall at its first meeting elect a Chairman, who shall subsequently convene the Committee and bring up its report. He shall also obtain from the Treasurer such grants as may have been voted for the purposes of the Committee. Committees elect Chairman.

XLVII. All Committees and individuals to whom any work has been assigned by the Society shall pre- Report before November 1st.

sent to the Council, not later than the 1st November in each year, a report of the progress which has been made ; and, in cases where grants of money for scientific purposes have been entrusted to them, a statement of the sums which have been expended, and the balance of each grant which remains unexpended. Every Committee shall cease to exist on the 1st November, unless re-appointed.

Grants expire.

XLVIII. Grants of pecuniary aid for scientific purposes from the funds of the Society shall expire on the 1st November next following, unless it shall appear by a report that the recommendations on which they were granted have been acted on, or a continuation of them be ordered by the Council.

Personal expenses not to be paid.

XLIX. In grants of money to Committees and individuals, the Society shall not pay any personal expenses which may be incurred by the Members.

Alteration of laws.

L. No new law, or alteration or appeal of an existing law, shall be made except at the General Meeting in March, or at a Special General Meeting summoned for the purpose, as provided in Law XIX., and in pursuance of notice given at the preceding Ordinary Meeting of the Society.

Cases not provided for.

LI. Should any circumstance arise not provided for in these Laws, the Council is empowered to act as may seem to be best for the interests of the Society.

Sections.

LII. In order that the Members and Associates of the Society prosecuting particular departments of science may have opportunities of meeting and working together with fewer formal restraints than are necessary at the Ordinary Meetings of the Society, Sections may be established.

Names and number of Sections.

LIII.—Sections may be established for the following departments, viz.:—

Section A. Physical, Astronomical, and Mechanical Science, including Engineering.
Section B. Chemistry, Mineralogy, and Metallurgy.
Section C. Natural History and Geology.
Section D. The Microscope and its applications.
Section E. Geography and Ethnology.

Section F. Social Science and Statistics.
Section G. Literature and the Fine Arts, including Architecture.
Section H. Medical Science, including Physiology and Pathology.

LIV. The meetings of the Sections shall be for scientific objects only. Meetings of Sections.

LV. There shall be no membership of the Sections as distinguished from the membership of the Society. Members of Sections.

LVI. There shall be for each Section a Chairman to preside at the meetings, and Secretary to keep minutes of the proceedings, who shall jointly prepare and forward to one of the Secretaries of the Society, prior to the 1st of November in each year, a report of the proceedings of the Section during that year, and such report shall be submitted to the Council. Officers of Sections.

LVII. The Chairman and the Secretary of each Section shall be appointed at the first meeting of the Council after its election in March, in the first instance from Members of the Society who shall have signified to one of the Secretaries of the Society their willingness to undertake these offices, and subsequently from such as are recommended by the Section as fit and willing. Mode of appointment of Officers of Section.

LVIII. The first meeting of each Section in the year shall be fixed by the Council; subsequently the Section shall arrange its own days and hours of meeting, provided these be at fixed intervals. Times of meetings of Sections.

LIX. The Council shall have power to propose gentlemen not resident in Victoria, for election in the same manner as ordinary Members, as Corresponding Members of the Society. The Corresponding Members shall contribute to the Society papers which may be received as those of ordinary Members, and shall in return be entitled to receive copies of the Society's publications. Corresponding Members.

LX. Associates shall have the privileges of Members in respect to the Society's publications, in joining the Sections, and at the ordinary Meetings, with the exception that they shall not have the power of voting; they shall also not be eligible as Officers of the Society. Privileges of Associates.

MEMBERS

OF

The Royal Society of Victoria.

LIFE MEMBERS.

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Wyatt, Alfred, Esq., P.M., Yorick Club

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