1935.

NEW ZEALAND.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

(NINTH ANNUAL REPORT OF THE).

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MINISTER'S STATEMENT.

During my visit to attend the Imperial Conference in 1930, and again during my recent visit, I felt it my duty to take advantage of every opportunity to investigate at first hand various research activities and organizations in Great Britain, not only because of their relation to allied research activities in New Zealand, so that such money as we have available may be spent wisely with a minimum of overlapping, but also because a general picture of developments in both primary and secondary industries which are likely to influence our own industrial progress in New Zealand can best be obtained by personal visits to British research institutions and to new industrial organizations, and by talking to the experts and leaders in the actual atmosphere of these experimental undertakings.

Although my investigations in Great Britain in this direction were of necessity limited, I have been more than ordinarily impressed with what I have seen and heard, in its relation to our own future in New Zealand, and it appears desirable that in this connection I should in this review of the activities of the Department include a consideration of the relation of some of the researches in Britain to our own activities and needs. There have been amazing developments, for example, in food storage and transport, which are of vital interest to our own industries; similarly in regard to fuel, textiles, &c. In many directions there is an immense fund of new information in Great Britain of use to us, and at present there is perhaps too little general realization in New Zealand of what is being done and how the results of this work in all aspects of industry and social well-being may be translated and put into practical use for our benefit. It has been brought home to me that, in order to reap the benefit of all the research and development work being done for us in Great Britain, we must provide our own technical and research machinery for the application of these results in New Zealand. It will, of course, be appreciated that the fundamental researches on which industrial developments are ultimately based are international in character and origin, and that we in New Zealand have to take account of progress in all countries; yet, in so far as we are bound to Great Britain by our marketing interests, there is special need for continued co-operation and linking-up with the research activities of the Mother-country, particularly on common problems. There are, however, owing to special local conditions, many directions in which we in New Zealand need to take a lead on our own behalf. Moreover, a full understanding of research results abroad necessitates that we should give our own men the required amount of training so as to appreciate the fundamental principles involved, in order that the application of research results to the special circumstances in New Zealand may be exploited with more certainty.

WORK OF DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH.

The work of the Research Department falls into two main categories. First, those activities concerned with the provision of the scientific services on behalf of the other Departments or those proper to Government on behalf of the community; and, second, the research work which comes under the direction of the Research Council. The co-operation with industry in researches aimed at a long-range provision for the future progress and efficiency of those industries.

The Department of Scientific and Industrial Research itself is not charged with the administration of any governmental regulations, but rather with the provision of information which may be of assistance in framing regulations of a technical character or for the proper administration of such regulations. The extent of the work in the former category is not generally realized.

DOMINION LABORATORY.

In the Dominion Laboratory, for example, the chemical work required for the Health Department in the administration of Public Health Regulations and Food and Drugs Act is carried out; similarly the analytical work on behalf of the Customs Department, Police Department, Department of Industries and Commerce, the Mines Department, Highways Board, in regard to various regulations administered by these Departments. Governmental regulation in connection with many Departments is becoming, with changing times, increasingly technical, and calls for a laboratory service and staff of increasing reliability and efficiency. The Dominion Laboratory needs to keep constant touch with improved methods of analysis, &c., developed overseas, and this is effected mainly through periodicals and exchange of reports with corresponding organizations abroad, as well as by occasional visits overseas of members of its staff. For instance, in regard to coal and fuel generally, one of the staff has been sent to Britain to study new developments in regard to hydrogenation and other aspects of fuel-utilization.

GEOLOGICAL SURVEY.

The Geological Survey is primarily concerned with the mapping of geological formations in the country, and about one-third of New Zealand has so far been mapped. The geological maps and publications indicate the structure of the country and also define the probable mineral-bearing areas. This information is useful to miners, engineers, agriculturalists; and, in general, the aim is to survey the country's national resources. During the year, in addition to extending the area mapped in ordinary routine, the geological parties have carried out investigations into water-supply, soil-surveys, and also those detailed geological and geophysical surveys of special areas. The results in these new lines of activity have proved most useful, and are at present in course of publication. It must be remembered that in New Zealand it is probably correct to say that the surface soils, the investigations of which are in part a geological problem, are worth more than all the minerals buried beneath them. Again, coal is probably more important than all the metallic minerals. The progress in the stock-taking of our resources by the Geological Survey Branch is progressing as satisfactorily as the funds available permit. The work is necessarily slow, partly because of the necessity of the topographical mapping involved. It is hoped that this may be speeded up by co-operation with the air services through the supply of aeroplane maps. From my experience overseas, I have appreciated that our geological publications are a factor in advertising New Zealand abroad, and that they often form a base for the attraction of overseas capital in various ventures.

The Mineral Resources Department of the Imperial Institute is of considerable help to New Zealand in indicating market requirements for some of the rarer minerals.

METEOROLOGICAL SERVICES.

During the past year the weather-forecasting service has been improved by the preparation and supply to morning and evening papers and to the Radio Broadcasting Stations of special regional forecasts. In the preparation of these forecasts New Zealand is handicapped by the paucity of observations from the Tasman Sea, and to overcome, in part, this difficulty arrangements have been made for an increased number of telegraphed observations from Australia, and also by the development of new so-called "polar front" methods of forecasting. In the latter connection my Department is indebted to the assistance of Mr. Holmboe, of the Swedish Meteorological Service, who, owing to the misfortunes of the Elsworth Expedition, was enabled to spend six months at the Meteorological Office collaborating with its own officers.

During the year the Government has appreciated the probable growing demands of aviation for weather service, and extra staff has been taken on to prepare for and to cope with this work. Moreover, the Director has been sent overseas to Empire and international conferences to assist in drawing up a scheme of international co-operation of these services. At present there is a great need for development of better wireless services in connection with interchange of weather information, and this aspect of meteorology is at present under consideration.

The whole subject of weather and climatological services is being carefully organized so that such finance as is available may be productive of maximum results. Fortunately we have been able to build up an efficient staff to cope with the problems involved.

OBSERVATORIES.

Apart from the Meteorological Office, there are three astronomical and geophysical observatories under the control of the Department—

(1) The Dominion Observatory, at Wellington, charged with the time services of the Dominion and the main seismological work;
(2) The Magnetic Observatory, at Christchurch, where the main activities are magnetic, seismic, atmospheric electricity observations, and meteorology; and
(3) The Apia Observatory, where comprehensive geophysical and meteorological observations are undertaken, and for which the major part of the finance is found by the Carnegie Institute, the Rockefeller Foundation, and the Admiralty.

The various observatories are worked, as far as possible, in co-ordination.

During the past few years the maintaining of accurate time service has been facilitated by receipt of wireless time signals from abroad, and this has allowed the officers to devote more attention to a study of the seismological conditions in New Zealand, with the result that a much larger measure of understanding of local earthquake conditions is now available, and a number of publications have been issued on this subject.

RESEARCH ACTIVITIES.

It will be appreciated that among the various Departments and institutions—*e.g.*, Scientific and Industrial Research Department, Agriculture Department, Massey and Lincoln Colleges, and Cawthron Institute—we have a large amount of capital invested in land, buildings, equipment, and brains, and we have men who compare favourably with technical officers overseas. The work of the Research Council is, to advise on the co-ordination so far as is possible, of these research facilities to the common good without introducing, at the same time, a degree of rigid control which will stifle initiative, and contemporaneously to encourage flexibility and freedom from vested ideas or confirmed rule-of-thumb methods. Moreover, we are in New Zealand spending a fairly large sum in University education, and from the science departments many of the best men have to leave the country to find openings for their special abilities, and many of these are attaining to good positions abroad. It would appear desirable, in these days when the research and process control method is becoming almost invariably practised in modern industry, that New Zealand industries should absorb more of these men, since the country has expended a certain amount of money in training them.

During the past few years many of our industries have made considerable headway towards the appreciation of the place of science in industry. In our primary industries one may cite the cases of dairy, fruit, and wheat, which now possess research institutes of their own in connection with the Research Council. There are, in addition to the special research activities associated with definite sections of industry, many common research problems—*e.g.*, those relating to plant breeding and diseases, insect pests, soils, fuel, &c.—in which the Government and Research Council feel justified in taking a more direct sponsorship.

DAIRY.

Since the establishment of the new Dairy Board, the Dairy Research Institute has been reorganized. The finances of the Institute have been given more stability by a grant from the Dairy Board of £6,000 for a period of three years and a grant from the funds at the disposal of the Research Council of £5,000 per annum. The Institute is controlled by a Committee on which are representatives of the Dairy Board (3), Department of Agriculture, Research Council, Executive Commission of Agriculture, Massey College, and Dairy Factory Managers' Association. Steps are being taken to grant the Institute a fairly full measure of autonomy. During the past year the Institute has made notable progress, particularly in the direction of improving the starter cultures for cheesemaking, the providing of a method of more equitable payment of milk for cheesemaking, controlling the flavour of cheese by the use of special cultures, processing of cream, controlling food flavours in butter, package and storage of butter, and in the manufacture of ghee.

The Dairy Research Institute maintains the closest contact with the Dairy Board, and by annual meetings with factory-managers, as well as with the assistance of the Dairy Division, passes on the results of its research work to the dairy industry. Many of the results obtained have been new to the dairy industry and of world-wide interest.

For the previous three years the Institute has received a grant of £2,000 per annum from the Empire Marketing Board for special problems of common interest to New Zealand and the Mother-land. With the passing of the Empire Marketing Board this grant has now been extinguished, but the Institute still keeps in close touch with dairy-research organizations in the United Kingdom. These organizations are more specially interested in the production and treatment of liquid milk for consumption, which accounts for approximately 65 per cent. of the total milk produced in the United Kingdom. Whilst these institutes in the United Kingdom therefore naturally devote only a limited amount of attention to butter, cheese, and other dairy-products, it is obvious that we in New Zealand, who supply Britain with about half of the cheese consumed there and 28 per cent. of the butter, must from our own resources provide the research work necessary to maintain and continuously improve our high standard of quality. It naturally behoves our Dairy Board and the Research Institute to keep continuously in touch with the varying needs of our British consumers and ensure that New Zealand is providing them with the type and quality of produce which they require. This necessitates investigation into transport, storage, conditions of handling, tastes, and uses. The various research institutes in Great Britain have been of considerable assistance in technical examination of experimental produce, and I noticed everywhere a keen desire to co-operate with us in this way.

WOOL.

Owing to financial stringency, the Department's activities in regard to wool research have been much curtailed, although indirectly much information comes from other allied research activities. At Massey College, however, valuable work has been carried out on hereditary and growth characteristics of wool fibres, and, in addition, the Principal has developed a scheme for routine evaluation of fleeces from the point of view of hairy or medullated fibres. Moreover, both at Massey and Lincoln Colleges careful tests have been carried out on sheep-branding fluids. It is obvious, however, that from the point of view of the importance of the sheep and wool industry to New Zealand far too little organized research is being carried out. An important factor in wool investigation is the obtaining of reliable manufacturing opinion on the value of various types of fleece as a guide to eradication of harmful features or development and exploitation of valuable features.

During visits to Bradford, Leeds, &c., I took the opportunity of discussing these questions round the table with the British Wool Federation and the Wool Industries Research Station at Torridon, and I have been impressed with the good helpful spirit evinced by members of these organizations, which showed that they are very

interested in our problems and desirous of co-operating with us. In order to obtain full benefits from this co-operation and that it may be of fuller service in this direction, however, they impressed on me the desirability of a corresponding wool-research organization, from the growers' point of view, in New Zealand, and in this direction we are lacking. It is assuredly only too true that our crossbred wools are suffering from the competition of artificial fibres, and I was informed that some 100,000 bales of our crossbred wool were now being annually displaced by artificial silk; for instance, the head of a great mass-production clothing combine has largely replaced wool-worsted linings for coats and waistcoats by artificial silk. Some of the difficulties with wool which have led to this substitution have now been removed. Nevertheless, such cases illustrate the tendency. Consequently, it is necessary for us to be on the watch to improve our wool from the point of view of manufacturers' requirements, and to assist in the search for improved processing and new avenues of utilization of wool. This is a matter on which the primary producer should be even more interested than the manufacturer, and it was pleasing to note at Torridon that work had been undertaken on the perfection and commercial application of a new dry chlorination process of wool to eliminate shrinkage, to improve handling, and to eliminate skin irritation; also the new bleaching process now being widely used commercially to eliminate the yellowing of white flannel. There are also potential developments of channels for wider uses of established wool materials—*e.g.*, wool fabric for motor-car upholstery, wool-worsted cloth for coat-linings and for bathing-suits, all of which are made preferably from New-Zealand-type wools. I was assured that there is every reason to believe that wool has special characteristics not possessed by any competitive fibre, such as moisture absorption, insulating properties, elasticity, &c. It appears worth while to work up more exactly the reason for, and the extent of, these characteristics so that when the facts are established it would be possible to obtain the support of authoritative hygienists, physiologists, medical men, &c., whose opinions would undoubtedly affect public opinion in general favour of the use of wool. It will also be seen that the above efforts tend to increase the demand for our wool, and therefore the realizable price; and when it is realized that the United Kingdom alone is producing over 100,000,000 lb. of artificial silk, and the quantity is steadily increasing, it will be appreciated that some action on our part is worth while. The large works of British Celanese, Ltd., at Derby, employ some 15,000 workers.

MEAT.

During the year the Department has taken an active part in connection with the shipments of chilled beef from various freezing-works. This work consisted in the checking of the means of preventing bacterial and fungal infection of the beef on the killing-floor, and, prior to wrapping, the recording of the conditions of temperature and humidity during cooling and in transit to port; the checking-up of the instruments for indication of the carbon-dioxide content and temperature of the atmosphere in the holds during ocean transit. These data are used in relation to the interpretation of the condition of the beef on arrival in United Kingdom as regards bloom and quality as estimated by the officers of the Low Temperature Research Station in conjunction with the Meat Board. From the results of this work the best conditions of treatment are gradually being evolved, although much remains to be done in regard to the effects of various strains of bacteria and fungi which vary in growth-rate at any given temperature.

In general, the essential need before the Dominion is the maintenance of its reputation to produce high-quality meat, and every means of promoting quality must be exploited. The growth of the chilled-beef industry, which has developed largely from the research work of the Cambridge Low Temperature Research Station, which I visited, accompanied by the Chairman, Lord Rutherford of Nelson, makes it imperative that attention be devoted to the breeding of suitable types of beef animals in New Zealand, to highly efficient scientific control of factory, and to transport facilities, so that a ready demand will continue for our beef.

In addition to this, investigations at the Station and in New Zealand have revealed that equally close attention has to be devoted to the hygienic conditions of slaughter and handling and storage at the works in New Zealand if continuity of quality and condition were to be maintained and good prices secured at Smithfield. Attention of the Station is also being devoted, following our request, to the best methods of packing, storage, and transport of edible meat offals such as kidneys, livers, &c. Flavours in meat caused by oxidation changes proceeding in fats were receiving attention, and this work had a particular bearing upon New Zealand meat on account of the long period which it remained in transport and thereby was afforded an opportunity for the development of flavours.

In regard to pork and bacon the research work in progress possesses a wide significance in connection with our growing pig industry. A few years ago when the question of export of bacon from New Zealand was receiving consideration, this was considered to be out of the question because of deterioration of the fat during transport. Now the maintenance of bacon in an atmosphere of pure carbon-dioxide gas indicates that this trouble can be overcome, though it is not yet fully practicable. Further, the fact that high-quality bacon can be manufactured from New Zealand frozen pork has been demonstrated beyond question, and this has enabled New Zealand to find a place in the bacon market of Great Britain. The importance of the cold-storage investigations on meat to New Zealand is indicated by the fact that, in general, New Zealand chilled beef brings an increase in price of 1d. a pound in Great Britain, and if the Dominion fills its quota of chilled beef the increased value of chilled beef over frozen beef will reach a total of the order of £50,000 per annum.

The Cambridge Low Temperature Research Station is one of three research stations maintained by the Food Investigation Board attached to the British Department of Scientific and Industrial Research, and on which New Zealand is represented. The other stations are Ditton, where there is an experimental ship's hold for carrying out refrigeration and dunnage trials, and Aberdeen, where problems of refrigeration and storage of fish are investigated. The total cost of the work is £50,000 per annum, of which New Zealand contributed last year £3,000—towards which the Meat Board made a grant of £1,250, the Fruit Board £400, and the Dairy Board £200, and the New Zealand Government £1,150. The work of the Food Investigation Board has undoubtedly helped considerably in improving conditions of storage and transport, so that our produce is now arriving on the British market in a condition more nearly approaching its pristine freshness.

FRUIT.

The fruit-research organization in New Zealand has been strengthened and stabilized by the contribution from growers through the provisions of the Orchard Tax Amendment Act, which will ensure a steady progressive programme of work to be laid out.

My recent visit to England caused me to become very impressed with the value of maintaining a high reputation for quality and storability in regard to our fruit exported. New Zealand fruit is there held in high esteem because of its quality. It is in this respect that research can help by being able to guide growers and shippers towards even higher standards, and by enabling the production costs to be lessened. The year has seen marked advances in this respect; a clue has been found to a possible remedy for the serious corky-pit disease of apples and pears; the importance of using sprays of appropriate toxic strength and applied to the trees in a thorough manner is now realized, and appears as a possible means of reducing costs; new systems of stowage and modified temperatures in transporting-vessels appear likely to reduce wastage and effect savings in costs. It is appropriate that New Zealand's fruit-research activities cover the complete range from the orchard soil to the consumer overseas, so that every aspect of the industry is subjected to constant scientific study.

I was pleased to note that in Great Britain new New Zealand fruit products were being successfully marketed, and I feel that in this respect further exploitation of fruit juices and canning is well worthy of attention. The Low Temperature Station at Cambridge has carried out valuable work which assists in these directions. I noted that work was in progress on a low-temperature concentration process for passion-fruit which may reduce freight charges owing to the concentration and cheaper packing charges. I also visited the New Zealand Passion-fruit Juice Factory at Slough, where juice from Kerikeri is treated.

I saw evidence of the rapid development of gas storage of fruit in Great Britain, and, while this method of prolonging the life of stored fruit represents a distinct advance in scientific achievement, its general adoption will make necessary profound economic adjustments in our fruit industry, enabling, as it will do, the English fruit crop to be available for consumption over a much longer period of the year. An important question therefore arises in guiding the future of the fruit industry into such channels as will enable it to fulfil requirements of our overseas customers differing from or additional to those at the present time.

WHEAT.

Largely following upon the attention which the Wheat Research Institute has devoted to the breeding and selection of wheat, its proper harvesting, storage, blending, and to baking processes, this industry is now on a more stable basis, and the public are receiving a bread of much more even quality and higher standard generally. There still remains much to be done, and I was impressed by the attention which was being devoted to wheat-breeding at various research stations, and to baking and milling problems generally, in a number of centres in Great Britain. This indicates that New Zealand should keep in line by pursuing wheat research assiduously, and by so doing stimulate development towards the production of improved wheats and new wheat products.

The organization of the New Zealand Wheat Research Institute is almost unique in the world, in that it is jointly run by growers, millers, and bakers in co-operation, and consumers represented by the Government. There is no doubt that this has led to more harmonious relationships between these partners in the industry.

During the year the first crossbred wheat bred in New Zealand (Cross 7) was grown on a commercial scale and has maintained its standard of yield and quality, so that in future a strain peculiarly suited to local requirements will be available. Every endeavour has been made to ascertain methods for improving flour quality, and investigations of the influence of soil moisture, of different storage methods, and of modifications in milling and baking practices have been under examination. The use which is being made of the services of the Institute still continues to increase, and each year sees a larger number of tests put through by those desirous of effecting improvements in their wheat growing, milling, or baking methods.

SOIL-SURVEY.

While it is a truism that New Zealand's greatest source of wealth lies in its soil, and that strikingly good use has been made of our soil resources during the comparatively brief period which the country has been settled, yet the question arises as to how much we really do know of the potentialities of our land resources. Recently there have come very radical changes in the technique of soil-survey practices, so that modern methods are much better designed to afford sound advice on problems of land-utilization. Taken in association with the Dominion's advantageous climate, our soils can be remarkably productive of a wide range of crops, and the present surveys are designed to indicate possible extensions of certain crop areas, the adaptability of soils for their appropriate pastures, best manurial and cultural treatments, and their relations to stock nutrition, health,

and production. The survey of the Waipa County conducted upon very detailed lines will provide information applicable to much of the Waikato and King Country districts. That of the Ashburton and Levels Counties will be a valuable guide to irrigation practices on the Canterbury Plains. Realizing that there is necessity for taking a long and sound view for the development of our lands, it has been decided to extend the area under survey, so that this year it is hoped to complete the Hawke's Bay and North Auckland Districts. At the same time comprehensive agricultural farm-management and other relative surveys will be carried out in these districts, with a view to understanding the land-utilization problems of these areas.

In a national stock-taking of a country predominantly agricultural, it is fundamentally important to apply scientific attention to our soil resources so that these resources may be fully husbanded, and so that information may be available regarding all possible extensions of their use. In looking to the future development of New Zealand and the question of our soils maintaining an ever-increasing population, investigations of soil potentialities should provide useful guidance. In Great Britain, as in many other countries, increased attention is being given to soil science and soil-survey, and our workers in New Zealand have received much help and inspiration from the work at Rothamsted, and the Macauley Institute for soil science at Aberdeen, while extensive use is made of the Imperial Bureaux of Soils centred at Rothamsted.

PLANT RESEARCH.

The close attention which has been devoted to pasture problems during the year by the Plant Research Station continues to prove of advantage to the farming industry, which, utilizing better strains of grasses and clovers, is now able to secure better carrying-capacity, better results from top-dressing, and a more even supply of feed throughout the year. At Jeallotts Hill and the Plant Breeding Station at Aberystwyth in England I was very impressed by the attention which was being devoted to pasture-management and grass-utilization. The various effects of stocking pastures at different seasons with different classes of animals showed some striking results, the underlying principles being of direct application in New Zealand, where pasture-maintenance constitutes one of the farmer's main problems. The progress of knowledge in regard to grass conservation by artificial drying and the preservation of high feeding value associated with this treatment, indicate that these developments have much economic significance in such an excellent grass-producing country as is New Zealand.

The work of the Plant Research Station at Palmerston North has, during the year included work dealing with the relation of pasture-growth to feed taints. This investigation has been carried out in collaboration with the Dairy Research Institute, and concerns a problem of considerable moment in regard to ensuring the absence of undesirable flavours from butter and cheese. The outcome of this investigation is likely to result in distinct economic changes in farm-management practice in some dairying districts. The work at the Station has been characterized during the year by distinct progress in all of its activities. An introductory book on the "Botanical and Economic Characteristics of the Grasses of New Zealand" has been completed, and is now in the course of publication. A close watch is being constantly maintained on all new species of plants, especially weeds, which are reported from year to year as established in New Zealand.

Analyses have been made of the herbage samples produced from the Marton mowing trials from month to month, so that a full knowledge of the nutritive characteristics of pastures at all stages of growth during the year is being acquired.

In view of the importance of top-dressing with superphosphate and carbonate of lime, researches on the reactions of these materials in the soil have given definite information of the rate of percolation and the speed at which the reversion of superphosphate takes place in the presence of lime, and in this instance it has been interesting to find that limestone from the Waikari and Cheviot districts has proved

much more effective in reverting superphosphate than that selected from certain other localities. Progress has been made in the study of certain fungous diseases of farm crops, but the development of control and remedial measures is a slow process, and every endeavour is being made to test out thoroughly all new specifics designed to check the serious losses occasioned by fungi. Plant breeding and selection work on farm crops such as rape, lucerne, potatoes, and peas is yielding useful results, and this work will render it possible to improve the standard yields of all of these crops to a higher level than they are at the present time. The Plant Research Station, dealing as it does with all aspects of economic plants, is in a position to ensure a balanced development and sound progress in the farming industry.

IMPERIAL AGRICULTURAL RESEARCH BUREAUX.

While in England I visited the headquarters of some of the Agricultural Research Bureaux, and, in discussions of their organization with the secretary, Sir David Chadwick, became directly acquainted with their activities and the relation of these to questions which confront research workers in New Zealand. These bureaux are engaged upon a most useful work, and their essentially Imperial character and organization merit our close interest and support. At Aberystwyth I saw the work of the Bureau for Plant Breeding. At Farnham House I saw something of the work done to provide supplies of useful insects for various parts of the Empire in order to maintain control over noxious species of insects and plants; at Slough, interesting researches upon fumigants for the control of insects and fungi affecting stored products is in progress; the wide range of activities at the Cambridge Low Temperature Research Station are of very real importance to our meat, dairy, fruit, and fish industries. While there was a number of other research centres which time did not permit me to visit, I am also aware of their real significance to us in New Zealand, and their encouragement of researches on an Imperial scale is certainly likely to have profound influence in the introduction of new knowledge which will prove of much advantage in a time of changing industrial methods such as exists at present.

The Dominion, in contributing to the support of the inter-Imperial research activities which function through these bureaux, is participating in a work which plays a very important part in cementing together, on very sound lines, bonds of Empire, because through its research activities a community of interest is developed, a wide range of contacts is effected, and a stimulation is given to the production of quality goods, which upholds the Empire standard of reputation, which is traditional in this respect.

The ten Imperial Bureaux deal with entomology, mycology, soil science, animal health, animal nutrition, plant genetics (2), fruit production, animal genetics, and agricultural parasitology, and a mere reference to their titles will indicate how completely they provide a means for dealing with a wide range of agricultural problems. Each of these bureaux, by maintenance of contact with the Dominion through the local correspondents, effect a rapid interchange of scientific views, and enables New Zealand to be kept abreast of all advances that are made in any part of the world.

FUEL.

The resources and supply of fuel, both coal and liquid fuel, are of vital importance not only to industry, but to the whole community, and it is important that the Government should keep up to date regarding developments overseas, and also as to the extent and nature of our own resources in relation to modern trends in usage. For several years, in co-operation with the Mines Department and coal-owners, work had been carried out at the Dominion Laboratory on the characteristics of New Zealand coals in regard to various avenues of utilization, and a valuable series of bulletins has been published. With the advent of financial stringency these activities were of necessity curtailed, and we had to be content with keeping up to date a bureau of information on overseas developments. With the advent

of hydrogenation of coal into oil and the unemployment in the mining industry, it appeared necessary to explore the position somewhat more intensively, and accordingly an officer who had carried out most of the chemical work on our New Zealand coals was sent to Britain to study at first hand the newer developments in coal treatment so that at the appropriate time similar activity may be encouraged in New Zealand.

The position was placed before the House in a statement during the 1934 session, and since then the main development has been the increased probability of success of the hydrogenation plant of the I.C.I. at Billingham, although it will probably be not until at least a year hence that the plant will have been running sufficiently long to indicate the modification and improvements which may reduce the high capital cost of such an undertaking so that it may be a safe venture under New Zealand conditions. While in England I discussed these questions at length with the directors of oil companies and with Imperial chemical industries, and also during a visit to the large British Fuel Research Station at Greenwich. The extent and work of the fuel research is very impressive. The capital cost of the plant, &c., was approximately £300,000, and the total staff numbered about 250. The results of laboratory investigations are carried out on a semi-commercial scale. The Station is carrying out a thorough survey of the coal resources of Great Britain, the object being to estimate the amounts of coal in the various fields and their suitability and particular value for various avenues of utilization, including marine, railway, and carbonization and hydrogenation purposes. The staff carries out official tests of various types of plant for the carbonization, &c., also investigations into cleaning of coal, use of pulverized coal, manufacture of metallurgical coke, gas retorts, hydrogenation of tar and creosote, utilization of benzole, &c. It would appear that we in New Zealand may be called upon to discuss seriously the possibility of operations for the production of oil in the near future. In the meantime two things are desirable. First, we should ascertain the probable hydrogenation as well as mining possibilities of various coalfields where there is readily available a reserve of, say, 40,000,000 tons. It should be noted that, roughly, a hydrogenation plant to produce New Zealand's petrol requirements will consume 800,000 tons of coal per year and employ of the order of 1,600 men in mining, and a considerable number of men, say, 800 to 1,000, in the plant and subsidiary operations.

In the second place, it appears desirable to survey a little more closely the possibilities of producing flow oil or natural gas in New Zealand, since production of petrol from flow oil can be carried out at a much less price than from coal, and it is not improbable that the by-products of refining, &c., and allied manufactures might be quite as large a factor in relation to the unemployment position.

In so far as the Department's resources permit, and in conjunction with the Mines Department, inquiries are being pursued in both the above directions. A geophysical survey of part of Taranaki has shown that such methods are definitely applicable to the elucidation of underground structure favourable to oil accumulation, and my conversations overseas confirm that such work is worth while as a preliminary to the more expensive operations of actual exploratory boring. Geological work is also being directed to the general problems in connection with the above problems. It is obvious that very thorough and careful preliminary investigation along all the above lines is desirable before embarking on expenditure such as is called for in developmental schemes.

With regard to production of alcohol as a liquid fuel, a preliminary investigation of the problem has been prepared and published in the Department's journal.

PHORMIUM TENAX.

A step forward is being made in regard to cultivation of flax. During the year, in co-operation with flaxmillers and Massey College, an area of some 60 acres near Foxton has been planted with specially strong and high-yielding varieties so that supplies of pedigree roots may be available for large-scale planting, with all the benefits in improved material and decreased unit cost of production which will arise from such conditions. In addition, at the request of the Unemployment Board

and Development of Industries Committee, a comprehensive investigation is being made of the attributes of *Phormium* from the point of view of textiles, and arising from these investigations improved methods of decortication are approaching the final stages of development. It is not generally realized that much fundamental spade work needs to be done on the characteristics of the fibre as a guide to proper treatment before a large industry can be founded on *Phormium* for new avenues of utilization such as textiles, or for improvements of the finished fibre for cordage, and for other uses. I took the opportunity in Bradford of discussing with experts the attributes and suitability of woolpacks made from *Phormium* and was assured by all concerned that every assistance would be given in the development of packs for the trade. The prospects of *Phormium* seem reasonably hopeful if orderly development is pursued.

BUILDING RESEARCH STATION.

From the point of view of its value as a social service the British Research Department has established a Building Research Station at Watford, and I found a visit to this Station of great interest. At first sight one might be inclined to think that research in such directions can hardly be practicable, but the esteem in which the Station is held by the building industry and architects and their active co-operation in the work show that it fills a very real need. The Station has made investigations, for instance, into the quality of bricks with a view to advising the manufacturer and building contractor and to setting up standards of quality which will safeguard both consumer, architect, and reputable brick-makers; similarly, in regard to cement and the principles of steel structure for building construction so as to obtain maximum strength at minimum cost. This work is of considerable value to New Zealand, where the results are now being applied by the special committee dealing with earthquake construction.

One interesting feature of the work of value to New Zealand was the use of certain types of volcanic ash for concrete and mortar. Such material imparts valuable properties to cements, endowing them with resistance to chemical attack and enabling a smaller proportion of cement to be used. Samples of our ashes had previously been tested by the Dominion Laboratory and also sent to the Building Research Station, and it is pleasing to note that some of them have the desired properties which, interestingly enough, are the basis of the old Roman cements, which are alleged to be stronger than the stones which they bind together.

Many other interesting lines of investigation were being pursued with practical results, including methods of testing the stresses and strains of piles, girders, &c., with a view to more economic design, heating and ventilation problems, &c., all assisted by grants from the building industry.

I was so impressed with this work that I arranged for a more direct linkage with this work with the results in connection with our New Zealand problems. There is no doubt that such work as I saw being carried out must have considerable effect on the cost of houses and the suitability of buildings to local conditions.

LEATHER AND PELTS.

The real advantage which scientific assistance can prove to an industry is well exemplified by the activities of the Leather Research Association. Contributing tanners have constantly been in receipt of scientific guidance in all their processes, with the result that the industry is economizing in costs in producing leather of such quality as enable it to withstand more and more successfully the competition of imported material, and, further, has been enabled to produce new types of leather which previously had to be secured from abroad. Of special interest has been the work done upon efficient methods of securing maximum tanning extracts from bark, and on the influence of dissolved salts and of oil in the wearing quality of sole leather. The value of the research work to the tanners has been greatly enhanced

by the contacts which have been maintained also with the abattoirs and freezing-works and with the boot-manufacturers, so that every link in the chain of leather production and utilization has been under supervision.

As regards pelts, investigations in regard to special processing methods have been continued in order to ascertain the possibility of utilizing our raw material in the manufacture of higher-quality leather goods. Shipments of trial pelts have been regularly despatched for evaluation by a special technical committee in England, and these consignments have been processed in different ways and reported on. The variable nature of the results have indicated so far that seasonal variations in the quality of the skin are greater than have been reckoned on previously.

GENERAL.

Space does not permit a detailed description of the other minor research stations which I was privileged to visit, including that to the British Paint and Varnish Research Association, where interesting work has been carried out on tests of kauri-gum products, and to concerns co-operating with work designed to improve pelts from New Zealand, &c. A large and increasing number of technical inquiries on New Zealand problems are directed into appropriate channels by the Department's liaison officer attached to the High Commissioner's Office. Everywhere I found a genuine interest in New Zealand's produce, and a desire to co-operate to the fullest extent with New Zealand in research work relating to our products and resources. It only remains for us to do our share and encourage this co-operation, which is to the interest of producer and consumer alike. Such work is true inter-Imperial co-operation.

G. W. FORBES,
MINISTER IN CHARGE OF SCIENTIFIC AND INDUSTRIAL RESEARCH DEPARTMENT.

SECRETARY'S REPORT.

The Council of Scientific and Industrial Research has held five meetings during the year.

The personnel of the Council is as follows:—

Professor Henry George Denham, D.Sc., M.A., Ph.D., Professor of Chemistry, Canterbury College, Christchurch (Chairman).
Professor John Malcolm, M.B., Ch.B., Professor of Physiology, University of Otago, Dunedin.
Mr. Theodore Rigg, M.Sc., Director, Cawthron Institute, Nelson.
Mr. Hugh Vickerman, D.S.O., O.B.E., M.Sc., M.Inst.C.E., Wellington.
Mr. George A. Pascoe, Chairman, Development of Industries Committee.
Mr. Archibald M. Seaman, F.P.A.N.Z., Public Accountant, Auckland.
Mr. Alfred H. Cockayne, Assistant Director-General of Agriculture, Wellington.
Professor William Riddet, B.Sc., Massey Agricultural College.
Dr. Ernest Marsden, M.C., D.Sc., F.R.S.N.Z. (Secretary).

Mr. George Shirtcliffe, owing to ill health, resigned from the Council during the year, and Professor H. G. Denham was appointed Chairman in his stead. Professor William Riddet was appointed to the vacancy created on the Council. The resignation of Mr. George Shirtcliffe was accepted with regret by the Council, and opportunity was taken to place on record its deep appreciation of the signal service rendered by him to the country in his capacity as Chairman.

During the year the Development of Industries Committee was reorganized and now functions under the chairmanship of the Hon. the Minister of Industries and Commerce, the Council being represented thereon by the Secretary. The Department has been regularly called upon to undertake certain of the investigations required by this Committee.

The expenditure of the Department during the year was as follows:—

Permanent services—	£
Head Office, publications, Research Scholarships, and miscellaneous	6,125
Dominion Laboratory (with branches)	11,766
Geological Survey	4,935
Meteorological Office	6,998
Apia Observatory	1,949
Dominion Observatory	1,485
Magnetic Observatory	1,906
Lincoln College	4,772
Research investigations	41,293
Total	81,229

The funds devoted to research work were derived from the following sources:—	£
Empire Marketing Board	2,592
Industries	10,456
Sales and miscellaneous recoveries	11,111
Consolidated Fund	17,134
Total	£41,293

Financial difficulties were experienced as acutely as ever during the year and were accentuated by the decision reached by the Imperial Economic Committee to maintain certain of the research organizations established by the Empire Marketing Board by means of definite apportionment of the costs between the United Kingdom, Crown colonies, and dominions concerned. This decision increased the actual expenditure of the Department during the year by some £3,600, assistance being given towards the Cambridge Low Temperature Research Station, Farnham House, Dried Products Research Station, Slough, and the Wool Research Institute, Torridon.

A grant of £5,000 was received from the Unemployment Board towards the cost of geophysical surveys carried out in the gold-mining areas of both Islands.

There has been a steady increase in the amount of miscellaneous work which the Department has been called upon to undertake during the year. Despite restrictions of staff and facilities all of these demands have been met as fully as possible, and the Department has been glad to be in a position to have rendered what is hoped to be very real assistance to a number of industries during a period of difficulty and economic stress.

DOMINION LABORATORY.

The Dominion Laboratory, and its branches in Auckland, Christchurch, and Dunedin, has been called upon to perform an increasing amount of analytical work for all Government Departments except the Department of Agriculture. Each year sees the need for further chemical attention being devoted to a whole range of problems connected with the very diverse activities undertaken by Government Departments. The staff of the Dominion Laboratory has been selected, trained, and has that wide experience which enables it to deal with a very wide range of problems.

The close watch which the Health Department maintains upon the quality of the food offered for sale in the Dominion results in that Department making the greatest use of the Laboratory services, well over eight thousand separate analyses of various foods being made. Milk-analyses figure prominently in this total, and it is gratifying to note that a steady trend towards higher-quality milk-supplies is manifest. A marked advance during the year has been the definite establishment of the

principle of a minimum of 8 per cent. of non-fatty solids in all milk offered for human consumption. In addition to milk-samples, almost the whole range of foodstuffs offered for sale in New Zealand were subjected to one or more tests during the year, and with very few exceptions all were found to conform to standards laid down in the Food and Drugs Act, which is in consequence revealing its substantial value as a means of safeguarding the public from fraud and ill health.

The Laboratory undertook a very large amount of work for the police during the year in connection with criminal investigations, and a review of the activities in this direction indicate the growing part which scientific assistance can play in the detection of crime and fraud.

The revival of interest in mining which has been maintained is responsible for continuation of the large number of samples submitted for assay. Many coal-analyses have been made, while mine-airs from collieries have been subjected to regular examination for the Mines Department. Research with the object of reducing excessive swelling of some New Zealand coals by means of weathering has been commenced.

Changes in the nature of various manufactured goods consequent upon the advances made in recent processing methods necessitate a constant supervision being maintained by the Customs Department. In this supervision the chemical assistance of the Laboratory is frequently called upon.

The range of materials purchased by various Government Departments have been regularly tested in order to ensure that their standard of quality is maintained. Researches concerned with coal, fruit, tree-sprays, soils, phormium, and ragwort have also been undertaken during the year.

METEOROLOGICAL BRANCH.

During the latter half of the financial year there was a very marked increase in the interest evinced by the public in aviation. The demand for air services not only throughout the Dominion, but also across the Tasman Sea, became very strong. As regards the Dominion itself, provision for such services has already been made, and a trans-Tasman service appears not far distant. Regular air services cannot be run safely and efficiently without adequate provision for the dissemination of the meteorological information required by pilots during their flights. This has been realized by the Government, and the necessary organization will be effected. Already the appointment of additional staff has been authorized, and the training of the new officers on the necessary lines will commence shortly.

The Director's report calls attention to the value of the climatological data being collected by the Meteorological Office and the need for ensuring that this shall not be lost sight of owing to the insistent demands at present arising for increased forecast services. There are few branches of industry in which adjustment to climatic conditions does not have to be made, and the more complete the information supplied the closer will be the adaptation to conditions. Not only, therefore, must the climatic data continue to be collected, but the results must be summarized, discussed, and published, so that the fullest use may be made of them.

The number of climatological stations at present maintained is as large as the staff of the Meteorological Branch can cope with, and many requests for additional stations have had to be refused.

Further progress has been made in the application of "frontal" methods of analysis of weather-charts as developed by the Norwegians. There is no doubt that this has led to an improvement in the weather forecasts and that the method will repay the closest study. In this connection the Meteorological Office staff had the benefit of the co-operation of Mr. J. Holmboe, the Norwegian meteorologist attached to the Lincoln Ellsworth Antarctic Expedition, until August, 1934.

The usual periodical publications containing various meteorological statistics have been published. Two papers of a more original type, intended as a preliminary basis for the study of modern methods of weather forecasting by local students of meteorology, have also been produced.

I desire once more to express appreciation of the extremely valuable work done by the numerous voluntary observers, on whose co-operation the success of the Meteorological Branch depends.

GEOLOGICAL SURVEY.

Since last year's report was presented the Geological Survey has published a palæontological bulletin, an important memoir dealing with the Devonian fossils of the Reefton district. In addition, the maps to accompany an areal bulletin were printed.

Detailed geological examinations were carried out in three regions, but only in one did this work proceed throughout the full season. The mapping of two subdivisions was finished and that of two new ones begun. Soil-work was actively continued in Waipa County, and rather extended reconnaissances were made in Ashburton, Levels and Southland counties. Detailed geological investigations proceeding and accompanying the operations of the geophysical parties at Waihi, New Plymouth, Mahakipawa, Reefton, and at several localities in Otago and Southland absorbed the whole time of one geologist and a part of that of several others. The importance of a sufficient supply of good cool water in dairying has long been recognized and is increasingly urgent, so two officers were detailed for a period to investigate water-conditions in the Taranaki, Waikato, and Piako districts.

The preparation of a geological map of New Zealand, the stock-taking of its mineral resources, and the publication of the data available proceeds all too slowly. In the last few years the professional officers engaged on this fundamental work of the Geological Survey have been reduced owing to death and resignation. The maps and reports of the Geological Survey, the finished product of its activities, are the basic raw material required in elucidating many of the problems of mining, agriculture, and water-supply. To preserve a proper balance and perspective, to prevent the grave misapprehensions liable to arise when the facts are known only in part, it is desirable that the rate of production be increased.

REPORTS OF RESEARCH COMMITTEES OF THE COUNCIL OF SCIENTIFIC AND INDUSTRIAL RESEARCH.

DAIRY RESEARCH INSTITUTE.

Dairy Research Management Committee: Mr. A. Morton (Chairman), Messrs. G. A. Marchant, W. E. Hale, A. Linton, T. C. Brash, Dr. C. J. Reakes, Messrs. W. Singleton, J. Murray, Quentin Donald, and Professor H. G. Denham. Director of Research: Professor Wm. Riddet. Secretary: Dr. E. Marsden.

During the year the Committee sustained severe losses through the deaths of Sir George Fowlds, who had acted as Chairman since the inception of the Dairy Research Institute, and of Mr. Dynes Fulton, who was also an original member of the Committee.

Mr. A. Morton was appointed Chairman in succession to Sir George Fowlds.

The Dairy Research Institute has during the year made material progress with problems affecting the manufacture of butter and cheese. Whilst, as in past years, practical cheese and butter experiments have formed important parts of the work, more attention has been devoted to fundamental questions relating to the manufacture of these products. It is becoming increasingly evident that emphasis must be placed on arriving at a clearer understanding than now obtains of the fundamental changes occurring in the manufacture of butter and cheese. This principle, already clearly established in the application of science to other industries, is well demonstrated by the progress made in the year under review.

Cheese.—With respect to cheesemaking, outstanding advances have been made in regard to the control of the vigour of starters, the role of bacteria in the ripening of cheese, the chemical changes occurring in the manufacture of cheese, and the devising of a simple yet equitable method of payment for cheese-milk. The observation that bacteriophage occurs in starter cultures has cleared up many baffling phenomena, and although this knowledge has not yet provided a solution of all starter difficulties it has yielded a new and definite line of attack, which in time should prove effective. Knowledge of the respective parts played by starter, rennet, and lacto-bacilli now brings the possibility of controlling the flavour of cheese within reasonable measure of practicability. Work on the chemistry of cheesemaking promises to put cheesemaking practices on a scientific basis, thereby providing a means of eliminating chance failures. The introduction of an inexpensive casein-test and the formulation of an equitable method of payment for milk for cheesemaking should remove long-standing objections which some suppliers have had to the distribution of co-operative cheese-factory proceeds.

Butter.—Work on buttermaking, though less extensive, is none the less important. The fundamental factors affecting the flavour and composition of butter are matters of greatest interest to the butter industry. It is essential to obtain an adequate explanation for the variations that occur in butterfat from day to day and season to season. Feed is of supreme importance. Unfortunately, there is no definite local information on the effect of either stage of growth or species of pasture-plants on the butterfat secreted by the cow grazing on pasture. Trials initiated at Morrinsville with respect to feed tains suggest important modifications of methods of grassland management or of treatment of cream in dairy factories. Experiments projected for next dairying season should test the validity of these suggestions. Equally important are the experiments on containers for the export of butter and the storage investigations, which aim at delivering butter with a fresh bloom appearance to consumers in distant markets.

Ghee.—Attempts to manufacture ghee make a new direction in which research can help the dairy industry. It is an effort to find another outlet for dairy-products. This is a function of the Institute which should be fostered, but which, on account of pressure of work in other directions in the past, has not been exercised.

The scope of activities of the Institute and the more outstanding results achieved in different projects are summarized in the following statements, prepared by the various research workers concerned. More detailed information is contained in the several publications enumerated at the end of this report.

Cheesemaking Investigations.

(*a*) *Starters.*—Since the work on cheese-ripening has led to the belief that acid-production is the main function of a starter culture, effort has been concentrated on attempts to produce cultures active in growth and free from sudden variations in vitality. A definite advance was made in the early part of the dairying season by the discovery of a new method for selecting strains of lactic streptococci for incorporation in starter cultures. Most starters in use up to the present have been mixtures of several strains of streptococci, and the question has often been raised as to whether (in cheese-manufacture) all these strains were essential to the action of the starter. The use of single strains as starter cultures had not, however, been a marked success in the past. During the year under review it was discovered that whereas several single strains might appear to have similar properties as judged by the usual criteria they could be sharply differentiated by the way in which they reacted to incubation in milk at 100° F. Some strains grew normally at this temperature; others, which had appeared similar at lower temperatures, proved to be very adversely affected by 100° F. Practical trials in the cheese-vat, where the curd is subjected to a temperature of 100° F. during part of the process, showed that only those strains which withstood this temperature produced acid at the rate desired by the cheesemaker. Several heat-resistant strains were isolated and have been used with success in commercial factories during the past season. They have proved, in general, more active as acid-producers than the majority of mixed cultures.

The sudden failure of starter cultures, whether mixed or single strains, still proved as great a source of trouble as ever. It had been shown in past years that failure was connected with aeration of the milk in which the culture was to be grown, but there was no indication of the manner in which air produced this effect. A chance observation in February, 1935, gave a clue to the problem and led eventually to a complete explanation of the mechanism of the phenomenon. It was shown that many cultures of lactic streptococci are infected with "bacteriophage," a virus-like agent which preys upon the bacteria. The existence of bacteriophage has been recognized among medical bacteriologists since 1915, but its occurrence in starter cultures has been hitherto unsuspected. The bacteriophage is apparently stimulated by aeration of the milk; it "flares up" and actually dissolves the bacteria in the starter.

The difficulty of dealing with this agent in such a way as to circumvent its action still has to be faced; but now that the mechanism of the reaction is known there is much greater hope of being able to cope with the problem successfully. It may be possible to immunize bacteria to the bacteriophage or to render conditions unsuitable for development of the phage. These lines are being investigated.

(*b*) *Cheese-ripening.*—Work in past years showed that neither starter bacteria nor rennet played a direct part in the development of cheese-flavour, and, further, that flavour did not develop in the absence of bacterial action. Attention was therefore directed to the group of bacteria known as "lacto-bacilli," which grow in the ripening cheese after the first week or two and subsequently reach enormous numbers. It appeared likely that they had some connection with flavour. Various strains of lacto-bacilli were isolated from samples of Cheddar cheese and pure cultures were added to cheese-vats. Control vats of the same milk were similarly made into cheese. As the cheese ripened it was found that the strains of lacto-bacilli added produced distinctive characteristic flavours. Certain strains imparted a mild aromatic flavour reminiscent of ripened cream-butter; others led to the development of a strong fruity fermented flavour, which has in the past suggested an infection with yeasts. All the results supported the theory that the flavour of Cheddar cheese is normally produced by lacto-bacilli which are present by chance in small numbers in the cheese-milk. The types present in the milk may vary from day to day, and hence the flavour of the cheese exhibits chance variations. It remains to be seen whether the deliberate development of distinctive flavours in cheese has commercial possibilities. There are still many technical details to work out in connection with the methods of adding such cultures to cheese-milk, but it is quite evident that here is a method of modifying flavours in cheese should this prove desirable.

(*c*) *Chemistry of Cheesemaking.*—Further investigations have been made of the possible causes of the anomalous whey-acidity readings during the later stages of the cheesemaking process, and an attempt has been made to obtain some more definite information on the nature of the acidity changes in the whey during the making process, and the type of cheese obtained. The factors studied included the mineral and lactose content of the milk, the rate of development of acidity during the making process, and the acidity at which the vat was run. It was shown that a high acidity at the "whey-running" stage caused an increased loss of minerals in the whey and a corresponding reduction in the mineral-content of the curd and cheese. Since the minerals in the curd are chiefly responsible for the neutralization of the lactic acid formed, this depletion of the minerals results in a less complete neutralization, and the whey acidities later in the process are consequently higher than in a corresponding vat run at a lower acidity. Low-test milk, which usually has a lower mineral-content than high-test milk, was found to give higher whey acidities for the same reason. The other factors investigated were found to be of little importance in affecting the significance of whey acidities. The knowledge of mineral losses has thrown considerable light on the relationship between the type of milk and the running acidity on the one hand and the quality of the resultant cheese on the other.

The effect of an artificial increase in the lactose-content of cheese was also studied, and it was found that only a part of the added lactose was fermented, so that, although a larger amount of lactic acid was formed in the cheese and a distinctly acid flavour produced, the acidity did not rise high enough to produce an objectionable effect on either the body or flavour of the cheese.

(*d*) *Payment for Cheese-milk.*—The problem of devising a suitable system of payment for milk for cheesemaking resolves itself into three parts:—

(1) The development of a suitable test for casein which can be carried out in the factory at little cost and which will give reliable results on composite samples of milk:
(2) The establishment of a general average relationship between the values for fat and casein content of the milk and the yield of cheese obtained under commercial conditions:
(3) The choice of a simple and equitable system of apportioning the proceeds to the suppliers.

Work has been carried out at the Institute on this question during the past three years with the following results:—

(1) The Walker test, modified and improved, gives sufficiently reliable results on preservatized composite samples of mixed milk, both in the laboratory and in the hands of the factory-manager.

(2) The Walker test, in conjunction with the fat test, gives equally as reliable an indication of the cheese-yielding capacity of mixed milk as does the laboratory test for casein; and results have been collected from eighteen factories showing that there is a general average relationship in New Zealand commercial factories between fat and casein content of the milk and cheese yield. On the basis of the results a table has been drawn up showing the yield of cheese per 100 lb. milk for milks of varying fat and casein contents.

(3) It has been suggested that payment be made on the basis of the "cheese test," or estimated yield of cheese per 100 lb. milk, with a deduction at a certain rate per gallon to allow for differences in manufacturing costs of milks of high and low cheese-yielding capacity.

(*e*) *Adulteration of Cheese-milk by Addition of Water.*—It has been found necessary in the course of the work on payment for milk for cheesemaking to test the milk-supplies in several factories for the content of added water. The results have shown the presence, in a number of these supplies, of quantities of water which could only have been included in the milk by intentional adulteration. In factory A, for example, with thirty suppliers, one supply contained 24 per cent. added water, and a second contained 20 per cent., while four further supplies had over 10 per cent. added water. In factory B, with sixty-six suppliers, one supply contained 15 per cent., four had 10 per cent. to 15 per cent., and thirteen had 5 per cent. to 10 per cent. of added water. Suppliers should realize that the addition of water to milk, even for supply to cheese-factories, is a punishable offence. It should also be realized that by the addition of water to milk for cheese-factories no advantage is received by any one, and the whole body of suppliers is involved in a certain amount of loss due to the extra costs of manufacture and the higher losses of fat and casein, and the manager is placed in an invidious position in that he cannot obtain the expected cheese-yield and that the control of the cheesemaking process is made more difficult. Apart from these aspects of the question the addition of appreciable volumes of water of doubtful purity is a danger to the quality of the milk-supply.

(*f*) *Firmness of Curd.*—Difficulties due to softness of curd at the renneting stage are occasionally met with in most factories, and at times in some factories these difficulties have become of major importance. The manager is frequently obliged to add excessive quantities of rennet, with resultant deleterious effect on the quality of the cheese. The causes of the trouble are no doubt to some extent related to the feeding-conditions. Apart from the fact that dry weather may be a contributing cause, little is known in detail of the origin of the trouble. When time and opportunity have permitted, the Institute has directed attention to the problem. In some cases the curd is naturally soft, but hardens up rapidly with the development of acid in the cheese-vat. In the more difficult cases, however, the development or addition of acid only aggravates the trouble, and the only satisfactory means of overcoming it is the addition of calcium chloride to the milk before renneting. This involves some changes in the details of manufacturing procedure to prevent the development of a chippy curd.

Investigations at the Institute on the milk from individual cows of the Massey College herd have shown that, on the average, milk from Friesian cows gives softer curds than milk from Jersey cows. Furthermore, some cows have a tendency to give milk forming softer curds. This is in line with recent work in other countries on the same question.

(*g*) *Discoloration in Cheese.*—It is definitely established that discoloration is caused by bacterial action and that admission of air to a cheese through cracks or by the process of plugging hastens its appearance. High curing-temperatures also favour its development, as would be expected. Work during the past season has consisted in efforts to track down the responsible bacterium.

Chemical work led to the hypothesis that the sulphhydryl radicle is the chemical agent catalyzing oxidation of the annatto through the admission of air to the interior of the cheese. An appearance resembling typical discoloration could be produced by purely chemical means on the basis of this hypothesis. A search was therefore made for bacteria which produced sulphur compounds during their growth, and a selection of these were added as pure and as mixed cultures to vats of cheese-milk. Control cheeses, protected from infection, were made as usual. Examinations were made by cutting the cheeses in half after four months and six months. The results during the past season have been inconclusive. Discoloration occurred in so many of the controls that it is not possible to state with certainty that any of the added organisms had any connection with the trouble when it did occur in the experimental cheeses. It is evident that the causative organism of discoloration is of fairly common occurrence in cheese, and this fact tends to cast suspicion on lacto-bacilli, several strains of which were among the test organisms. It is evident, however, that either the responsible strain was not picked out or that some condition necessary for its action still eludes definition.

(*h*) *Sliminess in Milk.*—During work on discoloration in cheese numerous slime-producing organisms were isolated from milk and dairy-products. It seemed possible that these bacteria might have some connection with discoloration; their properties were therefore investigated fairly fully. They proved to have no influence on the development of acid in the cheese-vat even when present in very large numbers, and although the slimy curd produced appeared very objectionable during the making process there was relatively little effect to be observed in the mature cheeses. Some inoculated cheeses developed abnormal and undesirable flavours, but otherwise there was no difference between experimental and control cheeses, and in particular no discoloration was observed. Slime-producing organisms are more definitely objectionable in their effects in the liquid-milk trade.

(*i*) *Disinfectants and Cleansers.*—Several chemicals are in common use as cleansers and sterilizers for milking machines and utensils. Inefficient rinsing sometimes leaves quantities of these chemicals in machine-pipes, and hence they are subsequently found in the milk. This is undesirable; but there has been a lack of definite information as to how much trouble in cheese-manufacture is due to this cause. Cheesemakers have often considered slow acid-development in the vat to be due to the presence of chemicals used in the cleansing of milking-machines.

During the past year all the commonly used chemicals and sterilizers were added to milk in varying quantities. Vitality tests carried out on raw and on pasteurized samples of these milks enabled a determination to be made of the minimum amount of the various chemicals necessary to impede acid-production. The results demonstrated that none of the chemicals in an amount reasonably to be expected in a milk-supply gave any effect on acid-development. Trouble due to this cause in practice, therefore, would be expected only where deliberate additions were taking place.

(*j*) *Contamination from Milk-strainers.*—In order to determine the extent of contamination of one supplier's milk from that of another by the strainers used over the weighing-vat in cheese-factory practice a number of trials were made at the Institute factory using both cloth and metal strainers. The results showed that if good-quality milk followed inferior milk through a strainer the amount of contamination is so small as to be negligible and does not affect the grade of the good milk on the standards at present in force.

Buttermaking Investigations.

(*a*) *Butter-flavour.*—Flavour in butter is considered to be due mainly to the presence of traces of diacetyl, derived from the natural oxidation of a flavourless precurser—carbinol—which is produced by the starter organisms. Starters in use in New Zealand dairy factories have been found to be similar to those used in the United States in regard to their production of these substances. The amount of carbinol and diacetyl found in butter is dependent on the amounts added in the starter, as very little is actually developed in the cream during the customary mild ripening-process used in this country. Diacetyl tends to disappear from butter held in cold storage at 150° F., and most of the loss occurs during the early part of storage. The precursor (carbinol) content remains unchanged during storage.

While the proportion of carbinol-diacetyl substances is dependent on the degree of development of acidity by starters, they are not acidic substances. It has therefore been found possible to produce butters containing relatively large amounts of carbinol, with otherwise the typical properties of a butter made from "low acid" cream. The flavour, however, is still mild, owing to the fact that but little of the carbinol has changed to the flavour-substance, diacetyl. Present work is mainly directed towards the possibility of inducing some of the carbinol present in cream or butter to change over to the diacetyl form. If this is found to be practicable it might be possible to manufacture highly flavoured butters of low acidity and consequent good-keeping quality.

(*b*) *Composition of Butter.*—Butterfats from Friesian and Jersey cows were collected at intervals during the 1933-34 seasons and some of their chemical characteristics have now been determined. There is a marked seasonal variation in composition and a slight consistent difference due to breed. There is also a difference in composition from day to day which may be due to either weather conditions or feed.

This work is preliminary to a more extended investigation which is to be made next season into the variations in the composition of butterfat in New Zealand in relation to feed, breed, and period of lactation. It is considered that the keeping-quality, spreadability, and vitamin-content are related to the composition of the fat, but little is known with regard to the relation of these factors to one another.

(*c*) *Neutralization of Cream and Flavour of Butter.*—In 1924 attention was drawn by Mr. Valentine to various anomalies encountered in the neutralization of acid cream for the manufacture of butter. Since that time there has been no attempt to explain these anomalies beyond a brief report from this Institute in the monthly report contributed to the *N.Z. Exporter*. It has been realized that a full explanation of the difficulties experienced would only be possible after a fundamental study of the nature of the reactions taking place. During the past five years attention has been devoted to the subject at intervals when time has permitted, and some information has been obtained on various aspects of the subject. A method of checking neutralization by determination of the pH of the resulting butter has been developed, and an investigation has been made of the relationship of butter to keeping-quality and the incidence of "flatness of flavour." Within recent months some work has been published by workers in other countries on related problems. It appears from a casual glance at these results that they do not agree in full with experience in New Zealand factory practice. It has not yet been found possible to relate the work of this Institute to these results in detail, but it is hoped that a report on the whole problem will be ready for presentation to the industry early in the coming season.

(*d*) *Timber-taint.*—A previous small-scale investigation on the treatment of *Pinus radiata* for the prevention of timber-taint in butter packed in this timber had indicated a measure of control. During the past year an investigation on a larger scale was made, and the opportunity was also taken to try out both tawa and rimu boxes. Two different systems of treatment were used:—

(1) The Wiley double-spray treatment as used in Australia.
(2) A proprietary single-spray treatment, developed in New Zealand.

The results may be stated briefly as follows.

(1) The taint from *Pinus radiata* boxes was not adequately controlled by either system of treatment, and boxes of this timber, even after the application of the surface-treatment, were not suitable containers for butter.

(2) Tawa boxes after treatment still imparted to the surface of the butter a certain distinctive flavour reminiscent of the odour of the wood.

(3) The tawa boxes were very heavy, and the miller in the Manawatu district experienced considerable difficulty in obtaining supplies of suitable tawa.

(4) Treated O.B. rimu boxes were without appreciable effect on the flavour of the surface of the butter. In this respect they were quite the equals of the white-pine boxes used as controls. They showed, however, a greater tendency to split at the ends.

(5) Untreated O.B. rimu appeared also to be satisfactory. This point is now being further tested out.

(6) Butter packed in boxes treated according to either of the above systems was contaminated with formalin on the surface, but only to a very slight extent. It is possible that kiln-drying of the shooks after treatment, as is practised in Australia, would eliminate this trouble.

(*e*) *Insulating-properties of various Types of Butter-box.*—Differences of opinion have been expressed as to the extent and importance of the extra insulating effect of the thicker timber in the standard butter-box compared with the thinner Saranac box on the rate of rise of temperature in the packed butter during transport. Some information has been available on the subject from various sources in New Zealand, but records of the results have not been published, with details of the method, to provide a common ground of discussion. An investigation has therefore been made of the rate of change of temperature both inside the block of butter and at the edge on both the sides and ends when boxes of the various types were used as containers. As was to be expected, the standard box showed superior insulating-properties to the Saranac wire-bound boxes, but it is considered that the differences shown were not of sufficient magnitude to affect the quality of the butter except under poor conditions of transport. Attention was drawn to the necessity for care in the transport of butter from factory to store and from store to ship's hold (compare report from this Institute, 1931, and Report of Dairy Commission, 1934).

(*f*) *Storage of Butter.*—Extensive experiments have been made on the storage of butter. One-pound pats wrapped in various papers such as parchment, cellophane, and parchment backed by tin and aluminium foil have been placed in storage at various temperatures and in various containers such as white-pine boxes, tins, and tins under vacuum.

Chilling: Butter held at 40° (± 5°) F.—*i.e.*, under poor commercial conditions of chilling—were very stale after three months' storage. The 1 lb. pats held in vacuum tins were better than those held in boxes, but mould was present on the surface of most of the samples.

Samples held at 32° F. for three and a half to five months were distinctly better. All the pats held in boxes were badly tainted by fruit-taint, the store having previously been used for the storage of apples. All the tinned samples were free from taint, but were stale, particularly on the surface. Those packed in tins under vacuum were usually more attractive than boxed samples when the tin was opened, the surfaces being of better colour and flavour. When the pats were left in the opened containers for one or two weeks at 40° to 50° F. these original advantages of vacuum packing were found to disappear.

Butter stored (even in tins) for three and a half months at 32° F. which was originally first grade was found to have deteriorated nearly to second grade, and when kept for a week more at 40° to 50° F. was definitely stale. After five months' storage at 32° F. the surface of all of the butter-samples was so stale as to render the pats almost unsaleable.

Frozen samples: These were of the same types outlined in the foregoing section, and were held for three and a half to six months in a meat store at 14° F.

When the containers were first opened the judges showed no consistent preference for the quality of the interior of the tinned samples, or vacuum tinned samples, but the surfaces of the tinned samples were frequently preferable to those held in boxes. After holding the samples in their opened containers for one to two weeks at 40° to 50° F. the initial differences disappeared.

General remarks: (1) Tinning of butter is an advantage, as it is a means of providing butter with a perfect container, which eliminates the chances of absorption of outside taints and the development of surface-desiccation, producing "Primrose" colour.

(2) The vacuum has little, if any, permanent benefit.

(3) "Primrose" colour is definitely related to surface desiccation; not only the wrapper is concerned, but the wood of a white-pine has a definite hygroscopic action.

(4) Metal foils, such as aluminium and tinfoil, are effective in retarding development of surface-colour and taint in butter, except in the presence of strongly tainting substances such as volatile matter from fruit. Tinfoil is rather better than aluminium foil, but is more expensive.

(5) While the packing of pat-butter in parchment wrappers in tins certainly eliminates risk of absorbed taint and drying out during storage, these defects may develop as soon as the tin is opened. The use of metal foils backed with parchment is nearly as effective as tinning for storage, and, further, it markedly retards the development of defects when the butter is exposed to the air after opening up the tin.

(*g*) *Effect of Storage on the Body of Butter.*—The change in the body of butter during cold storage was investigated by means of extrusion pressure determinations. Conclusive evidence was obtained to show that the body of butter becomes definitely firmer when it is subjected to prolonged treatment at the normal cold-storage temperature.

(*h*) *Feed-flavours.*—It has been well known for long that certain plants, especially certain supplementary crops and weeds, cause undesirable flavours in butter. Some observant factory-managers have also maintained that at some seasons of the year difficulty is experienced in securing cream free of food taint when cows are fed only on good pasture. In the past it was uncertain whether this was attributable to the feed or to bacterial contamination, arising possibly from scouring of the cows, particularly in the spring months.

Investigations carried out at the Morrinsville Co-operative Dairy Co.'s factory, with the collaboration of the company and the Plant Research Station, have clearly shown that certain pastures impart a definite and characteristic flavour to the milk of cows grazing thereon. This flavour is quite independent of the extent of bacterial contamination of the cream. It is more intense in the cream produced at the evening milking than at the morning milking, a fact attributed, but not yet definitely proven, to be due to the proximity of the last feeding-period to the time of milking.

The flavour is especially prevalent when clover predominates in the pasture. It appears in cream from high-class pastures in the spring months when clovers tend to dominate perennial rye-grass and reduces in intensity as the rye-grass increases. Pastures in which clovers predominate for a longer time are correspondingly associated with the defect. Top-dressing with quick-acting phosphate manures has been commonly blamed, but careful investigation by officers of the Plant Research Station do not substantiate this belief. On the one hand, pastures brought to a high state of fertility by top-dressing and adequate stocking become dominant in perennial rye-grass, and although they give trouble for a short time in spring they soon get over the difficulty.

On the other hand, pastures not top-dressed at all often develop (on relatively poor land) a sole in which trefoils predominate, and these cause flavours, even more intense than white clover, when active growth commences in late October. Progress results indicate that modification of methods of grassland management and the grazing of cows on "grassy" paddocks may overcome the difficulty, but these are deductions which yet need to be proven by practical trial.

It is believed that, in addition to management of the pasture and of the herd, stage and rate of growth of the plants are important. It is also possible that special treatment of the cream may be a means of overcoming the defect without otherwise injuring the quality of the butter. These are matters which await clarification in experiments planned for the next dairying season.

(*i*) *Deodorization of Cream.*—Many butter-factories, in efforts to control feed taints, have installed plants to pasteurize cream in partial vacuum. These aim at volatilizing the odoriferous compounds and carrying them off in the steam. The Institute has been supplied, by the generosity of the makers, with two types of such plants, and trials are in progress to determine the influence of the treatment of the cream by these on the quality of the resultant butter. Results are not yet sufficiently advanced for report.

(*j*) *Butter-boxes and Mould-growth.*—Trials were carried out with the assistance of Mr. J. C. Neil, Field Mycologist, Plant Research Station, to determine the protection which different types of butter-boxes offer to the growth of mould on the surface of the butter packed therein. It was shown that the type of box and extent of infection are both important. With ordinary precautions to protect the timber from infection mould did not readily grow on the surface of butter packed in standard and sub-standard boxes, even when exposed to conditions specially conducive to mould-growth. Saranac boxes made from sawn timber were somewhat less resistant to mould-growth; it spread readily across the surface of the butter when the ends of the box sprung after handling. Boxes of this type made from rotary-peeled timber developed profuse growth of mould, both externally and internally, especially when the timber was of open texture and, as in the other case, when the ends sprung.

Infection of the timber with mould-spores accentuated the growth of mould, thereby emphasizing the need for hygienic milling and handling of butter-box timber. Treatments of susceptible timbers with fungicides brought about some improvement, but at the strengths used were not quite effective in avoiding trouble. This aspect needs further investigation. The wrapping of butter in parchment, sandwiching a layer of aluminium foil, proved an effective protection of the surface of the butter from mould-contamination; in contradistinction to this wrapping-material, ordinary parchment paper was readily pierced by mould mycelia originating on the surface of the timber. The investigations pointed plainly to the need for using butter-boxes which are well secured, especially at the ends, and do not readily admit air to the surface of the butter, and on which moisture would not readily condense during defrosting.

Ghee.

Over 1,000 lb. of tinned ghee of various types has been sent to various parts of the East from this Institute.

New Zealand cow butterfat melts at a lower temperature, and has a much deeper yellow colour than Indian buffalo milk-fat, commonly used in the preparation of Eastern ghee. Both these differences cause difficulties in adapting New Zealand cow butterfat to this trade. Reports received from the East on our products almost invariably condemned all samples which were not bleached, and the problem is further complicated by the fact that different regions appear to demand different types of products. The bleaching process has required a considerable amount of experimental work, and while it is now possible to avoid off-flavours in the process the bleached fat is still rendered more or less flavourless by the action of the bleaching-agent. The production of bleached butterfat of the correct flavour is still under investigation.

It was originally assumed that ghee could be made from surplus butter, but the materials so produced were far too mild in flavour to be of interest to Eastern buyers. It has now been found necessary to make ghee from specially ripened cream in order to obtain the characteristic flavour in the finished product.

The small commercial scale methods of manufacture that have been tried include—(1) direct evaporation of butter by closed steam and decantation; (2) centrifugal separation of melted butter; (3) bleaching of fat prepared by methods (1) or (2), and subsequent clarification in order to remove the bleaching-agents.

A shipment of 800 lb. was prepared by the Institute on behalf of a firm which made arrangements for its sale with an Eastern trading company.

Prices quoted by firms operating in various Eastern countries indicate that there is at present little hope of developing a more profitable trade in ghee than in butter. Pure ghee has to compete with products made from vegetable oils, which can be sold cheaply. Prices quoted by Eastern countries for pure ghee have mostly varied from about 10d. to fully 1s. (N.Z. currency) per pound, c.i.f. and e. Since 100 lb. of butter are required to make approximately 80 lb. ghee it is apparent that the manufacture of ghee, except of special quality for a limited trade, has to be viewed more as a means of disposing of surplus butter than as a highly remunerative venture.

Routine Work.

(*a*) *Analyses of Salt.*—For control purposes several samples of standard brands of salt have been analysed during the year. The results show that the brands in common use are of a high quality. One sample of a new brand has not given such satisfactory results, and managers would be well advised to submit samples of new brands of salt to qualified analysts before departing from brands which have been tested and found to give satisfaction, or, alternatively, to purchase salt according to a satisfactory formula guaranteed by the seller.

(*b*) *Milk-quality Control.*—The following tests were made daily on all milk supplied to the dairy factory: (1) Direct microscopic count; (2) standard agar plate count; (3) methylene-blue reductase test; (4) B. coli test; (5) curd test.

As has been observed in previous seasons, the grading of milk by the direct count, the reductase and curd tests, has shown good agreement between the three tests.

Daily determination of the bacterial-content of pasteurized milk by the standard agar plate method enabled a check to be kept on the efficiency of pasteurization throughout the season.

(*c*) *Vitality of Starter Cultures used in Cheese-manufacture.*—Records have been kept of the activity of starter cultures used in all cheesemaking experiments by means of the vitality-test in pasteurized whole milk and in reconstituted skim-milk as control. The latter test has provided a means of checking variations in the vitality of the starter distinct from influences caused by the milk.

(*d*) *Cream-quality Control.*—The quality of cream-supplies has been determined by means of the standard agar plate count and the B. coli test on both raw and pasteurized creams. It is seldom that the count of pasteurized cream exceeds a few hundred per cubic centimetre, and frequently the count is less than one hundred with no coli present in 1 cc.

(*e*) *Control of Yeasts and Moulds in Butter.*—Some time was devoted to this matter. Yeasts were found to predominate in all counts carried out, and investigations showed that the main source of these was the churn. An appreciable reduction in the yeast-count was obtained by filling the churn about three-quarters with boiling water and maintaining at boiling-point for a period of one hour. Such treatment, while effectively reducing the yeast-count, was considered to be too drastic and liable to injure the structure of the churn if practised too frequently. Thorough steaming and rinsing with boiling water regularly before and after use was found to restrict the yeast-count within reasonable limits. It is proposed to continue the work on this subject during the forthcoming season.

Dissemination of Results.

The fourth annual factory-managers' week was held during the first week in May, when fifty-seven managers and first assistants were present at the Institute. A monthly bulletin was supplied to the *Dairy Exporter*. Addresses were given at various meetings convened by the New Zealand Dairy Factory Managers' Association, dairy companies, and the National Dairy Conference. The following technical publications were issued during the year:—

Institute Publication No.	Title.	Author.	Journal.
49	Observations on Sudden Changes in the Rate of Acid Formation in Milk by Cultures of Lactic Steptococci	H. R. Whitehead and G. A. Cox	J. Dairy Research.
53	Dairy Factory By-products and Drainage Wastes ..	F. H. McDowall ..	J. R. San. Ins., N.Z. Branch.
55	The Influence of Lactic Streptococci on the Ripening of Cheddar Cheese	I. R. Sherwood and H. R. Whitehead	J. Dairy Research.
57	A Simple Method for Detecting "Non-acid" Milk ..	G. A. Cox	N.Z. Jour. Agri.
59	The Spreadability of Butter	G. M. Valentine and J. D. Sargent	N.Z. Jour. Sci. & Tech.
60	Selection of Starter Culture for Cheese-manufacture..	H. R. Whitehead and G. A. Cox	N.Z. Jour. Agri.
63	The Occurrence of Bacteriophage in Cultures of Lactic Streptococci	H. R. Whitehead and G. A. Cox	N.Z. Jour. Sci. & Tech.
66	Payment for Milk for Cheesemaking	F. H. McDowall ..	Exporter.

The following are in the press:—

Institute Publication No.	Title.	Author.	Journal.
	Studies in Cheddar-cheese Making—		
51	Part 1	F. H. McDowall and R. M. Dolby	..
52	Part 2	F. H. McDowall and R. M. Dolby	..
56	The Role of Rennet in the Ripening of Cheddar Cheese	I. R. Sherwood ..	..
61	The Estimation of Diacetyl and Acetyl Methyl Carbinol	C. R. Barnicoat ..	..
62	The Function of Pepsin and Rennet in the Ripening of Cheddar Cheese	I. R. Sherwood ..	..
64	The Estimation of Salt in Butter	F. H. McDowall and C. L. McDonald	..
65	Diacetyl in Cold-stored Butters	C. R. Barnicoat ..	..
67	Rate of Temperature Change in Butter packed in Boxes of Different Types	F. H. McDowall ..	..
68	The Walker Test for Casein in Milk	„ ..	..
69	Bacteriophage Phenomena in Cultures of Lactic Streptococci	H. R. Whitehead and G. A. Cox	..
70	Estimation of Casein by Formol Titration after Precipitation with Acid	F. H. McDowall and A. K. R. McDowell	..

PLANT RESEARCH STATION.

The Plant Research Station is situated at Palmerston North, and is conducted in co-operation with the Department of Agriculture. The Station comprises a number of sections, some of which are concerned more with regular routine matters and others with research interests, and an endeavour is made to ensure a collaboration of effort which will serve the requirements of both Departments. Close association is maintained with the activities of the Wheat Research Institute, the Fruit Research Scheme, and the Dairy Research Institute, there being a number of problems of common interest to all the organizations under investigation.

The following report deals in brief form with those activities of the Station which receive financial assistance from the Department of Scientific and Industrial Research.

The Plant Research Station is directed by Mr. A. H. Cockayne.

Botanical Section.

(By Dr. H. H. Allan.)

(1) *Identification of Specimens and Advice thereon.*—As in previous years, this work has taken up a considerable portion of the time. Over three thousand specimens have been reported on from the usual sources. A number of new records of naturalized plants have been made, but, fortunately, none have been of major importance as weeds. There has, however, been evidence that a number of serious weeds are steadily increasing their areas—*e.g.*, *Psoralea pinnata*, *Eupatorium glandulosum*, *Carthamus lanatus* (saffron thistle). Since Mr. Zotov's return to duty he has been able to render valuable assistance in this work. It is pleasing again to note the interest taken by Stock Inspectors and Instructors in Agriculture in the weeds of their districts.

(2) *Herbarium.*—The policy of exchange with other institutions has been continued, and much valuable material accumulated. Additions have been made to all the sections, especially to that of introduced plants. Unfortunately, space is so limited that the herbarium is badly congested, and working-conditions for my assistants are far from adequate.

(3) *Library.*—The chief point to record is that the remaining volumes (some one hundred and fifty) of the library of the late Dr. L. Cockayne, so generously given to the Station, are now housed at the Station. There remain a considerable number of important pamphlets still to be received from the Dominion Museum. It is extremely unfortunate that space is so limited that it is impossible to arrange the library so as to be conveniently available to workers. The time is long overdue when the Station should have a properly-fitted-up room devoted to library use alone.

(4) *Field-work.*—During the year a number of excursions have been made as opportunity allowed. The work has been mainly devoted to study of indigenous grassland areas and ecological study on introduced plants. The most important piece of field-work accomplished was a botanical survey of certain areas in the Mackenzie Country, where an outbreak of dermatitis had occurred in sheep. A full report was furnished to the Director, with a list of species found, and recommendations for further investigations on the trouble.

(5) *Publications.*—During the year further articles on weeds and grasses have been contributed to the *New Zealand Journal of Agriculture*. The introductory book on the grasses of New Zealand has been completed and is now in course of publication, while the more detailed studies in the taxonomy of indigenous grasses has been proceeded with. The work on certain genera has reached the stage when publication of the results is possible. Papers of systematic and ecological import have been published or accepted for publication by the Royal Society of New Zealand, the Australian and New Zealand Society for the Advancement of Science, and the National Society of Horticulture of France.

(6) *Taxonomical Investigations.*—As indicated above, the systematic work on grasses and introduced plants has been carried on as in previous years. A good deal of work has also been accomplished on indigenous plants, and a number of other workers in this field have received assistance in their studies. A systematic study of *Pinus radiata*, with a view to elucidating the status of the forms found in New Zealand, has been commenced, as has also investigations of the pollen of this species.

(7) *International Lucerne Test.*—This was referred to in the last annual report, and a report is in preparation on the results of the first year's work. It is too early to draw any definite conclusions at present, but the work will be continued during the coming year.

(8) *Fruit Research.*—As in previous years, Mr. Woodhead has devoted his main efforts to this work. Assistance has also been given on the botanical side to the studies being made on "corky pit" and "mouldy core" in apples. The investigations concerned with fruit are dealt with in the Fruit Research Section of this report.

Chemical Section.

(By B. W. Doak.)

(1) *Marton Mowing Trials.*—Analyses of herbage samples from these have been continued, and a considerable amount of work has been carried out on soil samples from these trials. The study of the movement of phosphate from superphosphate, basic slag, and North African phosphates, each with and without lime applications, has been continued. The results so far are very interesting, but the work needs to be continued for several years to get reliable data.

Investigations into the movement of lime in the soil as affected by rates of application have shown that after two years less than one-fourth of a 2-ton-per-acre dressing remains as calcium carbonate. The remainder has reacted with the soil and is present in an exchangeable form. During this period there has been some movement of this exchangeable lime down below 6 in. in the soil. The effect of two ground limestones widely separated in chemical reactivity is being studied, both samples being applied in three grades of fineness.

(2) *Reversion of Superphosphate by Carbonate of Lime.*—As a result of conflicting reports on the ability of a super-lime mixture to eliminate the bad effects of super alone on the germination of turnip-seed an investigation into the ability of ground limestones to revert the water-soluble phosphate into water-insoluble phosphate, but still leaving the phosphate in a form available to plants, has been carried out. The presence of sufficient moisture is one of the main essentials to efficient reversion. In a dry condition very little reversion takes place in spite of several months in intimate mixture. In this case reversion cannot take place until the mixture is applied to the soil. If the soil is dry and the dry super-lime mixture is sown with turnip-seed considerable germination injury may take place. If, however, water is added to the mixture prior to sowing rapid reversion takes place, and if not too large amounts of water are added the mixture, after reversion, will be in a dry state suitable for drilling. Fineness of grinding of the lime considerably affects the rate of reversion, but differences inherent in the original limestone are responsible for the greatest differences. For example, Waikari and Cheviot ground limestones when used with super will correct the harmful effect of the super much more effectively than ground limestone from certain other districts, although the fineness of grinding and the total $CaCO_3$ may be practically the same.

(3) *HCN in White Clover.*—Determinations of the potential HCN-content of approximately one thousand two hundred samples of white clover have been carried out. This work has been done mainly in connection with the certification of white clover. Investigation has shown that, while the season-to-season variation in HCN-content may be fairly large, the day-to-day variation and the variation at different times of the day is not very great. There is a slight tendency towards higher HCN-content during the evening, but the results are not very conclusive.

Field Experimental Work.

(By J. Woodcock.)

(1) *Experimental Farm, Marton.*—Eleven trials are now being carried out under the "alternate mowing and grazing technique." Four investigate the relative merits of different kinds and methods of applying phosphatic or nitrogenous fertilizers. One of these, which has served its purpose, is shortly to be discontinued. Two experiments are concerned with an investigation into the liming of grassland, one being a trial of different methods of applying ground limestone while the other, which has only recently been established, aims at a determination of the relative merits of the coarse and fine fractions, respectively, of ground limestones from two sources. A further trial is designed to investigate the effect of pasture-cultivation with a penetrating harrow. The remainder of these trials are being carried out in collaboration with the Agrostologist to compare the production of various strains of grasses and clovers.

(2) *Ruakura Farm of Instruction.*—An experiment is being carried out here under the "mowing and grazing" technique which has for its object a comparison of no manure with super and with super plus lime, the latter being applied by two different methods. Lime is giving quite a marked response.

(3) *Observational Top-dressing Experiments.*—There are at present in existence throughout New Zealand 430 observational top-dressing experiments with the object of surveying grasslands from point of view of their response to lime, phosphate, and potash.

Responses to phosphate occur on most of the soil types on which trials have been laid down. Nevertheless, in some districts it has become evident that the effect from phosphate is only slight unless either lime or potash is applied in addition. In parts of Westland, Canterbury, and Southland the marked effect of lime has been recognized for many years. Trials in North Auckland now indicate that lime is a major limiting factor on the clay and the ironstone soils in that region. There are also some of the volcanic soils of South Auckland which respond quite well to lime.

Potash has been effective in experiments laid down in North Taranaki and in parts of South Taranaki. In the former region about a hundred small plots were laid down last spring to define, if possible, the limits of the potash responsive areas. Unfortunately, the subsequent abnormal dry summer conditions mitigated against securing on these the same marked results from potash as have occurred in previous experiments. In the Waihi district of the Auckland Province a number of trials recently laid down have indicated that good results from potash might be expected in that region. Various forms of phosphate are being compared in many trials. Slag is generally quite effective, but is not superior to super or to super and lime except in isolated cases. Rock phosphates have been invariably less beneficial than the above.

(4) *Demonstrations and Trials of Grass and Clover Strains* (in collaboration with the Agrostologist).—There has been an increase in the number of these demonstrations during the year. They are proving of great value not only for purposes of testing strains of grasses and clovers in different localities, but also for demonstrating to the farming community the importance of sowing approved strains and grass-seed mixtures. Such areas are almost ideal for field days, and in that respect are of great help to the instructional staff in furthering knowledge gained at research centres and in emphasizing the importance of sowing better strains of herbage plants. Alongside these demonstrational areas top-dressing experiments have been laid down.

(5) *Grazing Trials.*—There are nine experiments in which the production as measured in grazing-days of one field is compared with that of another differently treated. Four trials investigate the relative production of good rye-grass strains and poor rye-grass strains respectively, one trial in Canterbury compares fields treated with lime with an unlimed field, while two experiments in Taranaki are designed to further investigate the use of potash. At Marton Experimental Area records are being kept from fields under different methods of management.

(6) *Legume-inoculation Trials* (in collaboration with the Mycologist).—About one hundred simple experiments are being carried out to determine the effect of inoculating red and white clover, lupins, and field peas. Positive results from inoculation in a small number of the earlier trials resulted in an extension of the experiments during the past season, particularly those including clover. In a few trials on peas outstanding responses have been secured, although in others no differences have been observed. The evidence available so far, however, does not warrant any general recommendation regarding the inoculation of any of the crops mentioned.

(7) *Wheat-manuring.*—Only one experiment was laid down during the past season. During the coming year a large programme of work has been planned to investigate the use of nitrogenous fertilizers on wheat crops sown after a previous stubble crop. Experimental results in the past have indicated that under the latter conditions nitrogen applications are most likely to be effective, but that results vary considerably according to the season. Results from trials in Australia have indicated that response to nitrogen is largely bound up with the nitrogen-content of the soil, and this aspect will be investigated in the trials to be carried out by this Department during the coming season.

(8) *Wheat-variety Trials.*—Trials were carried out in collaboration with and on behalf of the Wheat Research Institute on twenty-five farms in the South Island, but seven of these experiments could not be harvested owing to lodging. In the majority of these the new variety, Cross 7, was compared with Solid-straw Tuscan.

In seven trials, including three in Marlborough, Cross 7 was superior to Tuscan, while in nine experiments it was lower in yield than Tuscan. The average difference was in favour of Solid-straw Tuscan to the extent of a quarter of a bushel per acre.

Seven trials included a comparison of a selection (13/28) of Solid-straw Tuscan brought out by the Agronomist with ordinary commercial Solid-straw Tuscan. Although there was no difference between the two when the average of all trials are taken into account, the superiority of the selection in a trial at the Pure Seed Station, Lincoln, suggests that it may be superior on certain soil types. Further trials in selected localities are to be laid down during the coming season.

Other varieties under trial were Jumbuck, Marquis, and certain Portugese varieties. The latter show promise of being very suitable as varieties for spring sowing, since at both centres where they were tried their yields were considerably better than those from Solid-straw Tuscan. They are to be under further trial during the coming season.

(9) *Wheat-rate of Seeding Trials.*—Nine trials were laid down in each of which seedings of 60 lb., 90 lb., 120 lb., and 150 lb. per acre were compared. Three of these had to be abandoned on account of lodging. The average increase in yield of 90 lb. seeding over 60 lb. was 1·7 bushels per acre, the 120 lb. seeding was better than 90 lb. on the average by 0·5 bushel, while the 150 lb. seeding showed an average increase over the 120 lb. seeding of 1·3 bushels per acre. These results tend to confirm those secured in previous seasons and support the contention that more rather than less seed should be used in practice.

(10) *Seed-treatment of Cereals* (in collaboration with Mycologist).—Further observational experiments were carried out to investigate the merits of Ceresan New as a seed-dressing for cereals. In several of these the thicker and more vigorous germination of the Ceresan-treated cereal was apparent in the early stages, but as the dry season mitigated against the occurrence of disease in any of the trials no data as to the effectiveness of Ceresan in combating smut as compared with formalin, copper carbonate, or no-treatment was available.

Mycological Laboratory.

(By Dr. G. H. Cunningham.)

(1) *Brassica Diseases.*—(*a*) Dry-rot (*Phoma lingam*): An investigation of the host-range of this disease has been completed and the results published. It is concluded that infection of swede crops from weed or cultivated crops is rare, except when following an infected swede crop. The variety of swede, Wilhelmsburger Otofte, has been substituted for Herning on the commercial seed-growing area at Colyton. It has proved under New Zealand conditions to be a better cropper and more resistant to club-root. The seed crop was exceptionally good, over 6,000 lb. of first-class seed being harvested from 2½ acres. Unfortunately, an inspection before harvest disclosed the presence of five plants infested with *Phoma lingam*, so that the seed cannot be certified as disease-free.

Stock seed has been produced for next season's seed-crop from bulbs selected on club-root-infected land.

(*b*) Club-root (*Plasmodiophora brassicae*): It has been found that the control of this disease by means of applications of lime is dependent on the type of soil. Dressings with lime which give satisfactory results on some soils are quite useless in others, thus accounting for the contradictory field results obtained in the past. An investigation is in progress to find the conditioning factors.

It has also been found that selected strains of rape, turnip, and swede that resist the disease in one locality may fail to do so in others. This has greatly complicated the work of selection, breeding, and testing of club-root-resistant lines.

(*c*) Turnip-mosaic: This has proved to be a virus disease transmissible from plant to plant by *Brevicoryne brassicae* and *Myzus persicae*, the aphides commonly found on brassicas. It has been shown to spread rapidly in the field and, in preliminary trials with rape, to cause 25-per-cent. reduction in yield. It has been found to have no connection with "mottled-heart" condition in swedes.

(2) *Cereal Diseases.*—(*a*) Rusts: An investigation is in progress, in collaboration with Dr. Stakman, of the University of Minnesota, and Dr. Waterhouse, of the University of Sydney, into the biotypes of the rust fungi of cereals and grasses present in New Zealand. This is a necessary preliminary into the work of producing rust-resistant varieties.

(*b*) Ear-rot of maize (*Fusarium moniliforme*): Experiments have shown that seed infected with this disease may be disinfected by dipping for ten minutes in water held at 137° F.; that this treatment reduces the amount of seedling-mortality caused by the disease, but that there is no connection between seed-infection and the incidence of the disease in the ears, the latter being due to air-borne infection.

(3) *Potato-diseases.*—(*a*) Corticium disease: It has been demonstrated that four years in grass is sufficient to eliminate corticium disease from the soil.

(*b*) Verticillium wilt: It has been found that there is no correlation between the presence of stem-end discoloration and verticillium infection in potato-tubers.

(4) *Diseases of Peas, Beans, Lupins, &c.*—(*a*) Virus diseases: It has been shown that sore-shin disease of blue lupins is caused by the virus of pea-mosaic and that it is transmitted by *Aphis rumicis*. Experiments indicate that it is not seed-borne.

The host-range of pea-mosaic (previously known to attack peas, broad beans, and red clover) has been extended to include blue lupins, sweet peas, alsike, and subterranean clover. The disease has a very marked effect on time of maturity and yield of garden peas. Two varieties have been found that, up to the present, are immune to the disease.

A mechanically transmissible mosaic disease has, for the first time, been demonstrated to occur in French beans. Preliminary experiments indicate that it may be transmissible by aphides.

(*b*) Bacterial-wilt of beans: A field experiment has demonstrated the possibility of cleaning up a lightly infected line of French beans by early and persistent rogueing of infected plants.

(4A) *Mangel-diseases.*—Field experiments with various organic-mercury-dust treatments for mangel-seed yielded no results. No disease developed in the plants from either the treated or the untreated seed.

(5) *Fruit-diseases.*—(*a*) Mouldy-core of Delicious apples: Investigations are in progress to determine the fungi responsible for the rot associated with this condition and the factors responsible for its occurrence.

(*b*) Damping-off of tomato seedlings: This trouble has been shown to be due to either of two fungi, *Corticium vagum* or *Phytophthora* spp. The best control was obtained by soil-disinfection with steam or with formalin.

(*c*) Leaf-mould of tomatoes: It was shown that the best measure of control of this disease was obtained with lime sulphur, sulphur dust, and Shirlan Ag.

(*d*) Virus disease of tomatoes: It has been shown that the virus disease of tomatoes in the Hutt Valley, formerly called "black stripe," is in reality a "spotted wilt" and that it is prevalent also in other parts of the Dominion.

(*e*) Strawberry virus disease: This has been shown to occur in the nurseries which supply the plants for Auckland commercial growers. Transmission of the disease has been obtained up to 100 per cent. by means of the strawberry aphis.

(*f*) Woodiness of passion-fruit: This is under investigation to determine the cause.

(6) *Tobacco-diseases.*—(*a*) Tobacco-mosaic: This virus disease has been shown to be spread mainly by human agency during the operation of pinching the laterals. It may also be carried in a very small percentage of the seed from infected plants and in the seed of tomatoes and the weed *Solanum nigrum*. All attempts at insect-transmission have failed.

(7) *Diseases of Ornamentals.*—A disease of roses, apparently due to a virus, and the rust diseases of pelargoniums, chrysanthemums, hollyhocks, and anemonies have been the subject of experiments with a view to finding means of control.

(8) *Mould Fungi of Foodstuffs.*—Investigations into the fungi responsible for mould deterioration in meat, butter, cheese, bacon, &c., have been carried out both in Great Britain and in conjunction with the Dairy Research Institute at Palmerston North. Much knowledge has been gained on the conditions which determine mould-attack, especially on chilled meat and on butter-boxes, thus enabling effective measures to be taken for its prevention.

(9) *Miscellaneous.*—(*a*) Silage-making: Experiments on the biological nature of the processes involved in the making of silage have shown that great improvements in quality may be made by the addition of bacterial culture, acid, whey, and molasses. Of these, whey and molasses have proved the most suitable in farm practice and enable good silage to be made from otherwise unsuitable material.

(*b*) Legume-cultures: Cultures for the inoculation of over 95,000 lb. of lucerne-seed have been forwarded to growers, a slight increase over last season.

(*c*) Pyrethrum: An investigation is in progress with several strains of Dalmatian pyrethrum (*Chrysanthemum cinerariaefolium*) to determine that showing the best extract for insecticidal purposes.

(*d*) Steam sterilization of soil: Experiments are in progress on the physical basis for the more exact determination and measurement of various processes for the steam sterilization of soils.

Agrostological Section.

(1) *Introduction.*—Field trials and farming experience have again emphasized the enormous value to New Zealand of "strain" in grasses and clovers as a factor to progress. Reports from the South Island from even the most arable districts are extremely encouraging, particularly from the point of view of the rye-grass strain used. New Zealand certified strains are being increasingly demanded. Plot trial, field trial, and farm-scale experience is also emphasizing the value of the New Zealand No. 1 white-clover type, and this fairly bids to rival certified perennial rye-grass in importance viewed from the point of view of strain.

A marked step forward in the year under review is the début of herbage seeds of a pedigree standard, some 220 acres having been sown out specifically for pedigree-seed-production purposes from seed originally bred at the Plant Research Station. Certain of this is grown on contract for the Department of Agriculture which will resell to interested merchants for seed-production purposes under certification.

The activities of the Station have been extended during the year in co-ordination with the Dairy Research Institute in the matter of our inquiry into the problem of feed flavours in cream and butter. Grassland research has a twofold scope: (1) The production of quantity and quality of herbage, and (2) the effects of such herbage as feed for animals and effect on animal products. Pedigree pastures demand a quantitative and qualitative measure, and the only satisfactory way of getting that measure is by means of the animal itself. The collaboratory work with the Dairy Research Institute on the influence of feeds, fed pure and in mixtures, in particular reference to feed flavours in butter is a welcome commencement of this work. Plant chemistry is an integral part of such an investigation, and the close co-operation of the Plant Research Chemist is being fully utilized. The Chemistry Section is of very great value to agrostology, both in research and as a routine aid to type-determination for certification purposes, particularly in so far as white clover is concerned.

The following are the main activities of the Agrostological Section during the year:

(2) *Perennial Rye-grass.*—(*a*) Plot trials: The dry weather experienced during the past summer has emphasized and defined very clearly the relative qualities of various types of rye-grass. The following points have been most marked:—

(i) The superior rust-resistance of the certified type over old pasture lines from Canterbury, Southland, Marlborough, and some from Wairarapa.

(ii) In a block of spring-sown plots the whole area was badly infested by fat-hen. In the late summer, when this had died out, the New Zealand certified type was conspicuous by its good, dense, and even sward. British Indigenous types showed a very marked thinning-out of the sward due to slow establishment and consequent smother.

(iii) In the main, Scottish, Irish, British Indigenous, and Australian lines have proved themselves to be definitely poorer than the New Zealand certified type.

(*b*) Elite-strain work: The block of ¾ acre of selected pedigree rye-grass was harvested for seed and yielded 762 lb. of roughly dressed seed. The major portion of this seed has been sown out locally on 20 acres for increase growing under contract.

The above yield will show how rapidly valuable stocks of seed may be increased. In 1934, 300 grammes were harvested; a portion of this (about 100 gr.) was sown out in a nursery-bed. Later some 33,000 plants were transplanted from this bed to the increase area of ¾ acre, from which 762 lb. of seed were harvested.

Owing to the very hot weather experienced during flowering-time this year's selection within the glasshouse set only a very small amount of seed. This has been sown out in boxes for later planting-out.

(*c*) Relative yield of pedigree mother seed rye-grass, ordinary certified rye-grass, and British Indigenous rye-grass: The following green-weights were taken on each of 100 plants of the following on 18th April, 1935:—

	Weight. Oz.	Relative.	Difference from Mother Seed.
Certified mother seed	591	100	..
Selection	1,175	199	+99
British Indigenous	303	51	—49

(*d*) Low germination of rye-grass: In an experiment designed to test the value of treating seed with hot water with the object of deciding whether or not any influence is made on the resulting seed crop no conclusive results were obtained. From other evidence it would appear that hot-water treatment has no beneficial effect.

A further experiment has been laid down at Winton and duplicated at Palmerston North. In this the problem is viewed from the strain point of view. A large number of as many strains as possible have been sown out. These will be harvested and germination figures determined.

(*e*) Single-plant study: Four thousand single plants (forty lines) of low ultra-violet testing South Island perennial rye-grass have been put out for selection and study.

(3) *Cocksfoot.*—(*a*) Single-plant study: Twelve hundred plants of Akaroa and Plains cocksfoot have been planted out for study. Up to the present no differences have been noted between Akaroa and Plains, but a marked non-uniformity of plant type in both Akaroa and Plains is noted.

(4) *White Clover.*—Selection of breeding of a large number of plants secured from different strains and the progress while a limited area of elite strains have been harvested and the seed sown for further augmentation of pedigree seed.

(5) Red clover, subterranean clover, *Lotus major*, and *Lespedeza* are undergoing strain trials designed to secure types suitable for New Zealand conditions.

(6) Plant-breeding on material taken from the selection already made is proceeding in regard to perennial rye-grass, Italian rye-grass, white clover, Montgomery red clover, and *Lotus major*.

(7) *Green-keeping Research.*—Selections of promising lawn-grass species have been made and these selections planted out as single plants for further tests. Further work in control of various pests has been undertaken, especially that dealing with the grass-grub *Porina*, caterpillar, earth-worm, weeds and fungous diseases of turf, has been continued.

(8) *Feed-flavour in Butter-investigation Work.*—This has been conducted under the direction of Professor Riddet, Dairy Research Institute, in collaboration with the Morrinsville Dairy Co. (Mr. Stirling), the Fields Division, and the Dairy Division of the Department of Agriculture. Forty farms were inspected and botanically analysed, and these were placed, roughly, into four main groups. The night and morning cream from these forty farms was graded on an 0–10 basis from a feed-intensity flavour point of view, and results were then correlated up with botanical composition of the farms.

The following points have been demonstrated :—

(*a*) Evening cream shows a feed intensity 3·6 times greater than the morning cream.
(*b*) The grass-dominant farms tend to be mild in feed-flavours, and no feed-flavours at all are in evidence where non-luscious grassiness predominates.
(*c*) Clover-dominant farms may give a high-feed-flavour intensity, and this may be given by white clover, red clover, suckling clover, or lucerne.
(*d*) Young luscious-growing herbage gives a greater intensity of feediness than older and more matured herbage of the same species.
(*e*) Weeds are not responsible for the general " tang " under investigation, but specific weeds may give rise to specific flavours.

The investigation to date points to modification of pasture management as a means of lessening feediness :—

(*a*) Every endeavour should be made to get several paddocks on the farm grass-dominant. Such paddocks should be used for day grazing (after 11 a.m. till milking-time in the evening) during periods of high general feediness.
(*b*) The more clovery paddocks should be utilized more for night grazing, when it would appear that the animal rations itself in so far as little grazing is done after midnight until after milking in the morning.
(*c*) Feeds should be utilized at a taller and more mature stage when possible during general periods of feediness.
(*d*) The most economical method to grass-dominance is by means of a high per-acre stock-concentration, and this can be best secured by a more liberal use of quick-acting phosphates, such as superphosphate, over the general farm, with occasional use of ammoniated super or nitrate of soda. Lime should be applied wherever ammoniated super is used.
(*e*) Ploughing up and reseeding to certified strains of grasses is probably the quickest means of getting some paddocks essentially grassy, and this is particularly true in the bringing-in process of low-fertility farms.

Fundamental work to arrive at the actual causative factor of feediness has been instituted in collaboration with the Dairy Research Institute at Palmerston North. The following areas have been sown out for grazing purposes and for stall-feeding in measured amounts, pure and in mixtures :—
(1) Perennial rye-grass, (2) Italian rye-grass, (3) cocksfoot, (4) white clover, (5) Montgomery red clover, (6) broad red clover, (7) suckling clover, (8) subterranean clover. These will be available for trial during the next spring.

Agronomy Section.

The work of the Agronomy Section deals mainly with investigations and research bearing on seed and crop production. It is undertaken partly at the Plant Research Station, Palmerston North, and partly at the Government Pure Seed Station, Lincoln.

Potatoes.—(*a*) Each year " seed " is raised and sold from the Pure Seed Station. The main objective is the production of pure and relatively virus-free " seed," and in this respect a satisfactory standard is being maintained, and there is a ready demand for the " seed " produced from the ten acres planted annually. The 1933–34 crop was very satisfactory ; the yield of the 1934–35 crop now about to be dug is relatively poor on account of the dry season.

(*b*) Trials of local Manawatu lines of " seed " were again grown and afforded further evidence of the necessity for growers to purchase certified " seed."

(*c*) A consignment of South American varieties of potatoes was received from the Imperial Bureau. These were planted rather late in the season, but sufficient " seed " will be secured to carry on. Importations were also made from the United States of America and Scotland.

Wheat.—(*a*) As in the past, pure and smut-free seed wheat of the more important varieties has been raised and distributed by the Pure Seed Station.

(*b*) A Pure Seed Station selection of Solid-straw Tuscan (13/28) has, for the fourth year in succession, outyielded College Tuscan by 2 bushels per acre. Unfortunately, this characteristic has not been maintained in general fields trials. A new variety which has also outyielded College Tuscan is now under field trial for the first time.

(*c*) Selection work in all varieties continues with the object of raising pure seed. This has been particularly important in the case of Cross 7. A very extensive yield trial of selections from Hunter's II has been continued.

Oats.—(*a*) Steps have been taken to raise pure seed of a number of commercial varieties, and some seed is now for the first time available for distribution.

(*b*) There is considerable variation to be found in certain varieties, particularly Algerians and Duns, and it will become necessary to test out these variants before seed is increased. This work is progressing in co-operation with the Crop Experimentalist.

(*c*) Observational trials of a number of varieties of which little is known are being conducted at four centres. Some of these varieties have been imported from Australia. The trials may be regarded as preliminary to any field trials that may be conducted, and permit the elimination of a large proportion of the varieties.

(*d*) Breeding-work has been commenced, and F 2 seed has been harvested of crosses between some of the varieties possessing special characteristics.

Lucerne.—(*a*) Yield trials have been laid down to compare Marlborough with Hunter River, South African, Tivicata, and Subtergrim. The two latter are varieties raised in New Zealand.

(*b*) Breeding commenced in 1931 and satisfactory progress has been attained. By selfing selected individuals it has been possible to locate parents which have produced satisfactory and vigorous progeny to L 2. There has been a steady loss in vigour and seed-production as selfing has advanced, but some families have retained a vigour equal to Marlborough and are extremely uniform in type. The work is progressing along three lines :—

(i) The parents which have produced the most vigorous inbred progenies, irrespective of type, have been seeded together. The resulting seed has been sown in an increase block and is being subjected to thorough rogueing. The progeny of this increase block will give the first bulk selection in 1935–36.

(ii) Selected parents have been hand-crossed one with another affording ninety separate crosses. These are to be grown out next season to determine the best combinations from which to build up a second selection.

(iii) The best of the L 2 progenies are to be hand-crossed next season. This is the best breeding-material available and it should be possible to build from it a highly satisfactory type.

(*c*) The pollination of lucerne is a matter of considerable importance, having as it has a direct bearing on seed-production and heterosis. A study has been made of wind and various insects as possible agents in this respect. The great importance of cross-fertilization in its effect upon seed-production and the vigour of the resultant plants has been amply demonstrated. Of the pollinating agents the following have been compared : Humble bee, Black Honey bee, Italian bee, Hybrid Honey bee, Carneolan, and Caucasian. The Apiary Instructor, Palmerston North, has co-operated in these trials.

Rape.—(*a*) Mother seed of the two types—Broad Leaf Essex and Giant—is produced each year for distribution to growers who are producing seed. That distributed this season is a blend of selected lines. Next season hybrid seed of the two most promising selections will be available, and following this will be the most promising selections from this cross. Thus an advance is being made each year.

(*b*) Breeding of rape types is progressing. Crosses between the various types have been made of which F 2 seed is available and also F 1 seed of back crosses.

Swedes and Turnips.—(*a*) Investigations regarding varietal nomenclature has been completed and the results offered for publication.

(*b*) Trials have again been undertaken to compare the yield and purity of New-Zealand-grown certified seed with that of imported seed.

Brassica Crosses.—(*a*) Inter-specific crosses were made originally to study hybridization between the various *Brassicae* in view of the interest being taken in seed-production.

(*b*) The majority of the roots died, but some of the hybrids produced F 2 seed. Back crosses have been made and some of the material may possibly be of economic interest.

Garden Peas.—(*a*) The production of pure lines of the more important varieties of garden peas continues to be an important activity of the Pure Seed Station, to which about 10 acres is devoted each year. These selected lines are purchased by merchants to replace existing stocks and build up from them their lines for export.

(*b*) Most of the selected lines were grown this season in comparison with stocks obtained from merchants, and in almost every case the selected lines were more vigorous and productive, and all were decidedly more uniform.

(*c*) A study of the tare leaves and other variants in peas has been continued. The problem is of great economic importance, but one that is proving very difficult to solve.

(*d*) Little actual breeding-work has been undertaken, but crosses between Great Crop and Lincoln have now reached F 4 and some segregates are promising.

Field Peas.—(*a*) Several new varieties of field peas have been placed under trial and a few are showing promise.

(*b*) An extensive programme of breeding has been undertaken and F 4 seed has been harvested. Field peas form an important crop in New Zealand and warrant considerable research in the development of a smooth, yellow pea with a colourless seed-coat that is better than those generally grown. These types are used in the manufacture of split peas. Improvement could also be effected in Partridge by producing an earlier ripening-strain for North Island conditions. Some promising material is available.

(*c*) Problems relating to the genetic analyses of certain seed characters have been concluded and the results are to appear in the *Journal of Agricultural Science.*

Onions.—(*a*) After several years' work, what appears to be a very desirable type of onion has been selected. Sufficient bulbs have been raised this past season to produce a quantity of seed next season.

(*b*) A yield trial designed to compare the selection with a number of standard varieties failed on account of dry weather.

Mangels.—A collection has been made of all varieties available in New Zealand. These are now growing and it is proposed to describe the varieties, and the Analytical Chemist intends to determine the dry-matter content of each.

WHEAT RESEARCH INSTITUTE.

(ANNUAL REPORT FOR THE YEAR ENDING 31ST MARCH, 1935.)

Advisory Committee: Professor H. G. Denham (Chairman), Messrs. C. H. Hewlett, Jas. Carr, W. W. Mulholland, P. R. Talbot, R. K. Ireland, W. S. Pratt, R. J. Lyon, C. E. Boon, C. Cowan, C. Lange, G. Fleetwood, J. W. Hadfield. Director of Research: Dr. F. W. Hilgendorf. Secretary: F. R. Callaghan.

1. Chemical Laboratory.

The Institute's working year ends on 31st December, when all the wheat of one season has been dealt with and that of the new season has not yet begun to reach the hands of merchants or millers. The tests of wheat made during the calendar year 1934 were as follows, the figures for the preceding year being inserted for comparison:—

——	1934.	1933.
Wheat-samples for milling and baking	3,214	2,314
Flour-samples for baking	2,417	3,019
Total bakings (including duplicates)	9,648	10,666
Moisture-determinations on wheat-samples	2,030	523

This list shows a considerable increase in the wheat-samples for milling and for moisture-testing, a reflex of the difficult harvest conditions consequent upon rain in January and February, 1934.

A large number of tests was made of the baking-quality of replicate samples within single lines, and also of samples of wheat harvested before and after rain, to show that bushel-weight alone is not a measure of quality when harvest conditions vary.

A trial was made of the quality of wheats from all parts of the world, composite samples being secured from reliable Institutions overseas. This trial showed that, with the exception of Canada, no part of the world produced wheat in any considerable degree superior to the average New Zealand product.

Although over three thousand lines of wheat were milled and baked, the number that the laboratory was asked to deal with was very much larger, and many hundreds of requests for tests had to be declined. This fact, combined with the very restricted space available for the laboratory, determined the Committee to move to more commodious premises and to install an additional flour-mill. The move was made in September, and has been very satisfactory. The new mill was in operation for the harvest rush, and all samples have been dealt with promptly.

2. Wheat-breeding.

The work of wheat-breeding is directed towards the discovery of a wheat which will yield as well as Tuscan and yet be of higher quality, so as to eliminate the present practice of importing Canadian flour. About thirteen thousand plots of wheat are grown each year, most of these being cross-breds between New Zealand and Canadian varieties.

Cross 7, the first cross-bred wheat to be distributed in New Zealand, was placed on the market and distributed under supervision. It had been tried in twenty-five localities from Blenheim to Oamaru and had proved just about as well as Tuscan, to give 2 per cent. more flour, and a 10 per cent. better loaf.

3. Field Observations.

Trials of the effect on yield of feeding off wheat with sheep were carried on for a second season, and showed that the feeding reduced the yield. It appears that wheat should not be fed unless it is for some special reason, as, for example, to prevent the crop from lodging.

Observations were continued for a third season on the soil-moisture and the resultant wheat-yields. It appears that a detailed study of the moisture at different periods of the wheat's growth will enable one to predict the yield with fair accuracy.

PHORMIUM RESEARCH.

REPORT OF WORK AT THE MASSEY AGRICULTURAL COLLEGE.

(By Dr. J. S. Yeates.)

During the past year work has continued, in general, along the same course as hitherto. It must be understood, however, that on account of the lack of funds and of increased time taken by teaching little progressive research has been possible, attention being given mostly to the immediate necessities of growing and propagating the plants. The work has, nevertheless, progressed hopefully in what is, after all, the main direction—namely, to be able to supply large numbers of fans of good varieties for large-scale planting. The Easton area is the tangible result of this development and represents a very definite step forward. The milling of the Ngaro leaf is also a definite milestone, being probably the first occasion on which a stripper has been able to work continuously for a period of days on one completely uniform variety. The main lines of work requiring specific comment are the following:—

Selection, Testing, and Propagation of Varieties.

Only one or two varieties have been added to our collection, but much useful information has been gathered concerning varieties we have had for some time.

Strength-tests have been carried out on samples of Ngaro fibre milled from our manurial plots in order to see if any great differences of strength exist among them. Other work has not allowed of extremely detailed work in this connection, but the tests failed to show any significant differences in strength.

The general conclusion from these tests of Ngaro is that the manures have made no appreciable difference to fibre percentage or to strength.

The Ngaro which was planted in March, 1929, has been ready to cut for a year or so, but cutting was delayed until land was available for extending the area of this variety. Cutting was finally carried out in the last week in February of this year. The ordinary hook-cutting method was employed, but the height of cutting was about 16 in. in order to spare the fans from too severe injury before transplanting.

The outside row of plants, having more available root-space, would naturally give a heavier yield. This row was therefore not included in the weighings. The leaf from each of the other plants (originally thirty) in each plot was weighed and recorded separately for each plant. In calculating the average yield per plant in the plots the "neutral" row where two plots met was not counted, nor were plants which were adjacent in the row to plants which had completely died out from yellow leaf. The bushes from which the leaf-samples had been cut for testing in December, 1933, were also omitted from the calculation.

Altogether there were twenty-four plots, being four replications of each of the following treatments, the rate of application per acre being given in each case :—

(*a*) Control : No treatment.
(*b*) P : Superphosphate (5 cwt.).
(*c*) P.K. : Superphosphate (5 cwt.) plus 3 cwt. 30 per cent. potash salts.
(*d*) N.P.K. : Superphosphate (5 cwt.) plus 3 cwt. 30 per cent. potash salts.
(*e*) P.N. : Superphosphate (5 cwt.) plus 2 cwt. ammonium sulphate.
(*f*) B.B. : 8 cwt. blood and bone.

The manures were applied on 13th November, 1929, and no subsequent dressings were given. Messrs. Imperial Chemical Industries, Ltd., who donated the ammonium sulphate for this and other tests are specially thanked for these gifts.

The general results of the manurial trials in terms of average yield per plant in all four plots subject to each treatment were as follow :—

	Lb.
Control	85·9
Superphosphate	93·6
Superphosphate plus potash	94·1
Superphosphate plus potash plus ammonia	92·2
Superphosphate plus ammonia	85·2
Blood and bone	94·2

Mr. A. W. Hudson has kindly made a statistical examination of the results and finds that on statistical grounds the results do not prove conclusively that any of the manures has increased the yield. In practice it can, however, be said that the increased yields given by four of the treatments as compared with the control stand more than an even chance of being due to the treatments themselves, and not to mere chance. One row running down all twenty-four plots had lime applied for 11 ft. on each side of it at a rate of 2 tons per acre. The average yield per plant in this limed row was 95·8 lb., compared with averages of 88·5 lb., 91·5 lb., and 89·9 lb. for three similar unlimed rows.

The manurial trials were set out primarily to investigate the possible effects of manures on the incidence of yellow leaf disease. A study of a plan on which every plant is marked fails to show a beneficial effect in this respect from the application of any of the above dressings. The following facts do, however, emerge from a consideration of this area :—

(*a*) Sudden and fatal attack by the disease frequently occurs in a plant growing otherwise under conditions suitable for vigorous growth. This point is indicated by the extra heavy yield of bushes adjacent (4 ft. away) to the dead plant.
(*b*) In general, the disease occurs sporadically through the plantation, but there is a tendency for two or three adjacent bushes to take the disease in the same year (not in subsequent years). This spread of the disease appears to be along the rows where the plants are closer (4 ft.) rather than between the rows, which are 11 ft. apart.

The term "yellow leaf" is not a good description of the disease as seen in this area. The plant frequently shows only traces of yellow colour, but the leaves curl and fall down in a manner which seems to indicate a cessation of water-supply from the roots.

The yield of leaf as tested by weighing immediately after cutting was 38·7 tons per acre over an area of nine-twentieths of an acre. The outside row, on account of better opportunities for growth, was not weighed, and in this test the plots which had earlier been side-leafed were not counted. The area considered was one continuous piece of land, not several isolated plots. The area included one-half of the space between these rows and the adjacent ones—*i.e.*, an area 11 ft. by 4 ft. was allowed for each plant originally set out, whether or not these plants had survived. This yield would probably have been increased to 45 tons per acre had the plants been cut at the customary height.

The weight of Ngaro leaf received by Messrs. Ross, Rough, and Co. off the total area, which is slightly less than 1 acre, was 35 tons 12¾ cwt., figures which are in good agreement with our recorded weight over a known area. This leaf yielded 6 tons 1½ cwt. of unscutched fibre, representing under 5 tons 18 cwt. of leaf to 1 ton of fibre. The leaf usually milled by Messrs. Ross, Rough, and Co. produces 1 ton of unscutched fibre from approximately 9 tons.

The other varieties which it is proposed to shift to the Easton area are S.S. and No. 22, of which we have sufficient to plant about 1½ acres each, and No. 37, of which we have enough to plant nearly 1 acre. Some tons of leaf from the first two of these varieties have been milled by Messrs. Ross, Rough, and Co., so that a sound opinion of their fibre-qualities can now be formed. The other variety (No. 37) is mostly in very young bushes and there will not be a great amount of its leaf for milling.

There are still a number of varieties which have never been tested at a mill, and it is hoped that the matter of expense in testing these may soon be overcome. Once they have been tested the plants of promise can be broken up and shifted either to the Easton area or to the Batchelar homestead, so vacating the main area on the College farm altogether. These varieties include a number of the most recent selections, which should produce good fibre.

Hybrid Seedlings.

In order to overcome the difficulty of growing thousands of hybrid seedlings to maturity on the College area an arrangement was made by which Mr. R. Macdonald, of Waikuku, took some 10,000 two-year-old crosses between Ngaro and S.S. last autumn. Mr. Macdonald will use these plants in his commercial plantation, but arrangements will be made to select, test, and remove a few of the best bushes when they are mature. In the summer 1933–34 a large quantity of hybrid seed from the same parents was procured, but the exceptionally early and dry season has almost entirely prevented its germination. In the past season, owing to the absence of flowers on the Ngaro and S.S., no more hybrid seed could be obtained.

Seed from a number of experimental crosses was obtained in 1933–34 and is growing well. On account of the scarcity of flowers in the past season the genetical work has been delayed for one year.

Yellow-Leaf Disease.

In February, 1934, it was noticed that a grub—apparently a species of *Porina*—was exceedingly common in the leaf-bases of badly diseased plants, but was scarce on healthy plants. Extensive tests have been made to see whether these grubs are directly or indirectly responsible for the disease. Up to the present time no such proof has been obtained. Variety No. 22 has now been in the nursery for seven years, first represented by four bushes, but over the last three and a half years by about seventy bushes. Although growing where plants within a few feet have taken the disease severely no plant of this variety has yet been affected.

The S.S. variety, on the other hand, growing alongside the variety No. 22 had a considerable amount of disease in it. The results of the Ngaro plantation show that, even with a variety which is readily killed by the disease, and on land such as occurs in the main area, which is very prone to yellow leaf, a good crop of leaf can nevertheless be obtained.

The Easton Area.

Once the basic soundness of the scheme for large-scale propagation of varieties was accepted it became necessary to have a sufficiently large area for such work, in a position where transport of plants and leaf to the mills should be reasonably cheap. The Easton area fulfils these requirements very well, and yet is fairly close to the College (about twenty-six miles). It is proposed to continue with the genetical and other nursery-work, including the initial stages of increasing by fans, in the present area at the Batchelar homestead. As soon as any variety proves itself on a small scale it can then be removed to the Easton area for large-scale trials and propagation.

General.

During the past year weighed amounts of leaf from a number of varieties covering the range from good to bad fibre plants have been supplied for shipment to Europe and also for examination at the Dominion Laboratory. These samples were required for tests to be made of the percentage and quality of cellulose in different varieties.

MINERAL-CONTENT OF PASTURES.

SEVENTH ANNUAL REPORT OF THE MINERAL-CONTENTS OF PASTURES INVESTIGATION AT THE CAWTHRON INSTITUTE.

The work mentioned in last year's report in connection with animal trials at Glenhope and with the manurial trials on the Marsden Estate at Stoke has been continued. In addition, some fundamental work on the reaction of soluble phosphates with the soil has been carried out.

1. Bush-sickness Investigations.

In previous reports mention has been made of the strikingly beneficial results obtained following the use of a Nelson-soil drench in preventing bush sickness at Glenhope. Last season this work was extended to include four treatments, as follow: Nelson soil, ignited in furnace; Whangarei limonite; Parapara limonite; and Nelson soil, unburnt (group continued from the previous season). The first three groups were made up from newly introduced animals.

The three new groups all gave satisfactory increases in weight throughout the season. There were no observable differences in the health of the animals in the several groups. Although the animals lost condition badly owing to hard conditions during the winter they all remained healthy. By October, 1934, these animals had regained a fair amount of condition and were sold in order to make room for new animals for the present season's experiments. The sheep which had been on Nelson soil for two years were sold at the same time; they were all perfectly healthy and in very good condition.

For this present season's experiments five groups of hoggets, introduced from healthy country, are being drenched twice weekly, using quantities of drench-material corresponding to equal amounts of soil. The treatments are as follow: control; Nelson soil; Nelson soil after extraction with dilute hydrochloric acid; liquid extract from Nelson soil; and Wakatu soil. This last soil was introduced in order to test another Nelson type of soil which is known to be healthy to stock. The acid-extract from Nelson soil was used to see if the active agent in preventing the development of bush sickness was easily extractable from soil. If the whole of the active agent were present in the liquid, then the residue of soil should be inactive in preventing bush sickness. It must be admitted that the process of extracting the soil was not very vigorous, so that the whole of the active agent might not be extracted; indeed, the live-weight data in Table I show that the extracted soil is still a good preventative of bush sickness, although there is an indication towards the end of the season that the animals of this group are not doing so well as those in some of the other groups.

TABLE I.—AVERAGE NET SHEEP-WEIGHTS, GLENHOPE, 1934–35.

Treatment.	12th October, 1934.	2nd November, 1934.	19th November, 1934.	27th November, 1934 (Shorn Wool).	17th December, 1934.	16th January, 1935.	14th February, 1935.	15th March, 1935.	18th April, 1935.
Nelson soil	63·9	66·8	74·2	4·2	73·8	76·3	76·0	81·4	87·6
Nelson extracted soil ..	63·9	68·3	74·8	3·2	74·8	78·3	79·0	80·8	84·2
Liquid extract (Nelson soil) ..	62·0	66·2	74·0	3·5	79·0	82·0	85·4	85·5	90·0
Wakatu soil	63·7	68·3	75·2	4·3	78·8	79·6	80·6	85·4	87·6
Control	62·7	67·6	73·8	3·8	74·4	75·6	75·6	74·8	76·4

The average weights of the experimental animals shown in Table I indicate that all groups, except the control, developed at approximately similar rates; if anything, the liquid extract has given slightly the best results. All the animals in the drench groups are to date (3rd May, 1935) perfectly healthy, with good bright wool, and a number are in sufficiently good condition to pass as butcher sheep. On the other hand, the animals in the control group have stopped putting on weight; two of them are definitely losing weight and are suffering severely from bush sickness. In all these animals the wool is harsh and dry and lacks lustre. All the groups will be carried through the winter to see whether any further developments from the above indications may occur.

This season's work has again demonstrated the great importance of soil as a factor in animal health and has shown that the beneficial properties of Nelson soil are associated with constituents soluble in dilute hydrochloric acid.

2. FERTILIZER TRIALS.

The mowing-trials, in which a comparison is being made of the yields from a worn-out pasture renovated by the application of fertilizers and from a pasture newly sown with certified seeds, have been continued.

The completed results for last season indicate that the greatest return from fertilizer applications is found with superphosphate. The use of 1½ cwt. superphosphate per acre increased the yield of dry matter by a little over 1,200 lb. per acre, while an additional 1½ cwt. superphosphate gave only a further 240 lb. of dry matter per acre. As was indicated in last year's report, it is somewhat surprising that on a soil deficient in phosphate, as the Marsden Estate soil type undoubtedly is, such a small application of superphosphate as 1½ cwt. per acre should give such great increases in yield, which are not very materially increased by a further application of 1½ cwt. per acre. The lack of response of this Nelson pasture to a December application of superphosphate has been confirmed this past season; the very dry weather has not been advantageous for bringing out any increase which might have followed the application.

Sulphate of ammonia has continued to give marked increases in yield during the spring period following application of the fertilizer in July. It is noticeable, however, that the depression in yield on the nitrogen plots during the summer period is becoming more marked season by season. Where sulphate of ammonia at the rate of 1½ cwt. per acre has been used without superphosphate the total yield is about 500 lb. of dry matter per acre lower than where 1½ cwt. superphosphate only has been used; both treatments give yields much greater than those corresponding to untreated or limed only plots.

Potash has not given any marked increase in yield on these trials.

On the renovated area growth has been good with a continuous improvement in the content of perennial rye-grass. From the following it will be seen that the newly-sown pasture, now four years old, is just approaching the old pasture in yield :—

TABLE II.—COMPARISON OF YIELDS OF DRY MATTER, IN POUNDS PER ACRE, FOR RENOVATED AND RESOWN PASTURE.

Season.	Untreated.		Complete Fertilizer.	
	Renovated.	Resown.	Renovated.	Resown.
1932–33	2,603·8	2,414·1	4,677·1	4,077·5
1933–34	1,611·7	1,545·0	3,219·4	3,264·6

It appears from these data that several seasons of growth are required before a resown pasture may reach a condition satisfactory for relatively high carrying-capacity. In the 1933–34 season the yields on both pastures were lower than in 1932–33 owing to the very dry weather experienced, but it is obvious that the resown pasture is at least as productive in the second season as the old renovated pasture.

On the resown area mowing-trials have been continued in the 1934–35 season, but as the season is not yet finished the yield data are not available. The season has been a relatively good one, and, particularly in the late summer and autumn, growth has been good.

Effect of Leniency of Cutting on Yield.

In March, 1933, an area, sown at the same time as the main experimental area discussed above, was set aside and top-dressed with sulphate of ammonia to see whether the total yield would be affected by cutting the pasture at three stages—(*a*) Short growth, about 2 in. to 3 in.; (*b*) medium growth, about 6 in.; and (*c*) ensilage and aftermath stages, after the pasture had been left in the late autumn to grow throughout the winter. A further dressing of sulphate of ammonia was given in the spring of 1933. A similar procedure was adopted during the 1934–35 season. Data for these two seasons are given in summarized form in Table III. In both seasons the ensilage plus aftermath cuts have outyielded the cuts from the two shorter stages. There does not seem to be any great advantage in allowing growth to proceed to the 6 in. stage as compared with the 2 in. to 3 in. stage, since the differences shown in the above table are probably not significant. Sulphate of ammonia has in all cases given marked increases in yield in the spring period, the increase being least in the case of the 6 in. growth and greatest in the case of the ensilage. Later in the season, however, there is a tendency for the treated plots to fall below the untreated plots in yield; this is particularly noticeable in the second season, in spite of the much more favourable conditions for pasture-growth in this season as compared with the first season. For the whole season the differences between treated and untreated plots, except ensilage, may not be significant.

Under the conditions of this mowing-trial it would appear that, while sulphate of ammonia will give increased growth of spring grass, the succeeding lower yield is liable to annul the spring advantage, whether the pasture is closely mown or is allowed to grow to a somewhat taller stage before cutting; on the ensilage plots marked increases are obtained from the use of sulphate of ammonia, but the succeeding aftermath on the treated plots may fall below that on the untreated plots. The total yields for the two cuts do show, however, a great increase where ammonium sulphate has been used.

TABLE III.—EFFECT OF LENIENCY OF CUTTING ON YIELD OF PASTURE.

(Pounds of dry matter per acre.)

Period.	Short Stage.		Medium Stage.		Ensilage and Aftermath.	
	Treated.	Untreated.	Treated.	Untreated.	Treated.	Untreated.
1st March, 1933, to 9th November, 1933	2,075·1	1,683·5	2,162·2	1,908·3	5,077·0*	4,102·1*
10th November, 1933, to 28th March, 1934 ..	339·4	320·3	399·9	374·2	561·7†	520·2†
Total, 1933–34	2,414·5	2,003·8	2,562·1	2,282·5	5,638·7	4,622·3
28th March, 1934, to 15th November, 1934 ..	2,436·6	2,153·0	2,336·6	2,227·0	6,313·5*	4,970·9*
29th March, 1935, to 26th April, 1935	1,615·7	1,710·8	1,471·9	1,683·4	1,641·7†	1,800·3†
Total, 1934–35	4,052·3	3,863·8	3,808·5	3,910·4	7,955·2	6,771·2

* Ensilage. † Aftermath.

3. Soil-phosphate Studies.

The reactions between soil and phosphate are of great interest not only from a scientific, but also from the economic, point of view.

Fundamental work on the extraction of phosphate from and fixation of added phosphate by soils has shown that the reactions are greatly dependent on the pH value of the suspension of soil and solution. The extraction of phosphate is least in the region pH 3–4, and the fixation of added phosphate is greatest in the region pH 3–5. On either side of these minima great increases in the quantities of phosphate in solution are found. Soil type, also, is important in governing the amounts of phosphoric acid in solution at any given pH value, whether the phosphate is derived from the soil itself or from added phosphate.

In the literature of this subject it is proved indirectly that oxides of iron and aluminium are probably the chief agents in fixing added phosphate. Soils freed from these oxides were therefore prepared with their clay fractions converted into sodium and calcium forms. Similar soils with these compounds present, either with or without organic matter, and soils freed from both organic matter and these oxides were also prepared. It was shown that when the iron and aluminium oxides (R_2O_3 compounds for convenience) were removed the fixation of added phosphate was very small; fixation due to organic matter was therefore negligible as compared with the fixation due to R_2O_3 compounds. By varying the concentration of phosphate in the solutions presented to the soils, at approximately constant pH values, it was shown that the percentage fixation decreases with increase of concentration of phosphate, the degree of reduction being dependent on the soil type. Under certain conditions the calcium clays fixed slightly more phosphate than the sodium clays, but the amount of phosphate fixed by the R_2O_3 compounds did not vary with the type of clay present.

The extraction of phosphate from soils after fixation depends on the pH value of the extracting solution and also on the type of solution; for example, 1-per-cent. citric acid and 0·02 M $NaHSO_4$ solutions both have a pH value of approximately 2·0, but the citric acid extracts much more phosphate than the hydrogen sulphate and does not suffer such great changes in pH value from reaction with the soil. The case of extraction varies from soil type to soil type. In general, the lower the fixing-power of the soil for added phosphate the more easily is the combined phosphate subsequently extracted.

From the results obtained it would appear that many New Zealand soils are capable of fixing large quantities of phosphate in a form which would probably be relatively unavailable to plants. In raising the pH value of the soil by liming fixation of added phosphate would be decreased. On acid soils of high fixing-power the use of basic superphosphate or basic slag would therefore probably be more satisfactory than the use of straight superphosphate.

4. General.

During the year the following Pasture Research publications have been published:—

No. 26. Soil Phosphate Studies. Part I: "Solubility of Soil Phosphate and Fixation of Added Phosphate at varying pH Values," by H. O. Askew.

No. 27. Soil Phosphate Studies. Part II: "Fixation of Phosphate by R_2O_3 Oxides in Sodium and Calcium Clays," by H. O. Askew.

H. O. Askew, Officer in Charge.

PAKIHI SOILS RESEARCH.

SEVENTH ANNUAL REPORT OF THE PAKIHI INVESTIGATIONS CONDUCTED BY THE CAWTHRON INSTITUTE.

Introduction.

With the very limited finance available work in connection with the pakihi reclamation has been restricted mainly to the maintenance of the small farm of 24 acres laid down in previous years and the oversight and top-dressing of the small experimental plots dealing with the use of lime, phosphatic manure, and the growth of different grasses and clovers. In addition, the plantations of shrubs and trees likely to prove serviceable for shelter purposes have been extended. Pampas-grass has also been planted to ascertain its value for fodder and shelter-purposes under pakihi conditions.

Small Farm.

Twenty-four acres of pasture were sown in two blocks of 11 acres and 13 acres respectively in March, 1932 and 1933. In both cases a good strike of grasses and clovers was obtained, and satisfactory sward-development has taken place. During the first year after establishment grazing was permitted only during the summer, autumn, and early winter months. In the second year grazing was conducted throughout the whole of the year.

Under such conditions of stocking and top-dressing at the rate of 2 cwt. of superphosphate per acre the pastures have improved, and more valuable grasses, such as perennial rye and cocksfoot, are now more prominent than was the case in the first season. Consolidation of the land has also taken place, and no difficulty has been experienced in holding stock on the pastures throughout the winter. During the summer and autumn it would have been possible to have taken a motor-car over practically the whole area which has been grassed. In order to maintain the lime-status of the pastures an additional $\frac{1}{2}$ ton of ground limestone per acre was applied in March, 1935, on the block originally

grassed in 1932. For convenience in handling the stock the 24-acre block has been subdivided into five fields varying in acreage from 1 acre up to 8·6 acres. The smaller fields have been reserved for hay and ensilage making and the provision of early spring feed. The other three fields have been grazed in rotation by dry stock.

During 1934 dry stock was maintained on the farm throughout the whole of the winter, and, with the exception of a small supplement of hay fed during the months of July, August, September, and part of October, were entirely dependent on pasture-growth. For the whole year 1934 the 24 acres maintained on an average fourteen head of young heifers, but, in addition, 2·6 acres were shut up for hay and 3·8 acres were shut up for ensilage in the early summer of 1934. It is estimated that these two fields gave approximately 3 tons of hay and 13 tons of prepared ensilage. The following table shows the number of grazing-days throughout the year 1934 on the 24-acre block:—

Number of Grazing-days on 24-acre Block.

	1933.	1934.	1935.
January	..	620	310
February	..	672	277
March	..	744	341
April	..	500	330
May	..	485	341
June	..	300	..
July	..	320*	..
August	..	310*	..
September	..	300*	..
October	..	310*	..
November	119	300	..
December	490	217	..
	609	5,078	1,599

* During these months hay at the rate of 50 lb. per day was fed.

The stock grazed on the pakihi pastures has kept in excellent condition, and certain heifers gained first and second prizes at the recent Agricultural and Pastoral Show at Westport. At the present time over 7 acres of the farm are shut up for spring feed and the ten head of dry stock are being carried successfully on 16 acres.

Experimental Plots.

The results obtained from the large number of small experimental plots confirm those of previous years. In connection with the use of lime, plots treated at the rate of 1 ton of ground limestone per acre began to show a marked falling-off in the fourth year. Where only ½ ton of ground limestone per acre has been used in the initial treatment of pakihi land partial failure of pasture occurred at the end of the second year. The results of these lime-tests indicate the desirability of liming at the rate of ½ ton of ground limestone per acre at the end of the third year after establishment.

The top-dressing of pakihi pastures has again proved of supreme importance in the maintenance of growth. Two hundredweight of superphosphate has given very satisfactory results, but where ensilage and hay are cut the use of potassic manures appears to be very desirable. In those cases where top-dressing has been discontinued very great deterioration in pastures has taken place, but it is interesting to note that plots which have in the past received Nauru rock phosphate have suffered much less than those which received either super or basic slag.

In connection with the trials of individual species of grasses and clovers the best results have been obtained with lotus, white clover, alsike, red clover, crested dogstail, and fog. Great improvement in the growth of all grasses has taken place as soon as lotus or white clover gained free entry into the plots of the individual grass species.

It is interesting to note that plots sown with mixed grasses and clovers six years ago and subject to annual top-dressing treatment continue to give heavy growth of lotus, cocksfoot, red clover, and other pasture components.

Pasture-establishment by Farmers.

The success which has been obtained by the Cawthron Institute in establishing pastures on pakihi land has encouraged farmers both at Westport, Onekaka, Collingwood, and Takaka to grass areas of pakihi land. Generally speaking, the methods which have been employed are those recommended by the Cawthron Institute, but in certain cases modifications have been made to meet the particular conditions ruling on the individual properties of farmers.

At Westport at least three areas, varying in acreage from 5 acres to 30 acres, have been sown with fair results. The financial position of farmers, however, in the provision of annual top-dressings has militated against obtaining optimum pasture-growth.

At Onekaka Mr. F. G. Gibbs has continued the grazing of his 75-acre pakihi farm, and during last season maintained an average of over twenty head of dairy cows during the whole of the milking-season. The cows milked well, and during drought periods more feed was available on the pakihi land than was the case on high-grade pastures on the alluvial flats in the vicinity. Less extensive developments in connection with the establishment of pastures on pakihi land have taken place in the Takaka district and also at Collingwood.

Flax Plantations.

Phormium tenax was planted several years ago on the plots of the Cawthron Institute at Sergeant's Hill. It is interesting to note that *Phormium tenax* planted in prepared holes treated with lime and fertilizer has done extremely well and compares favourably with flax planted after ploughing and disking the land. The best results with *Phormium tenax* have been obtained by using a complete treatment consisting of lime, followed by the use of super, potash, and ammonium sulphate. On those plots where phosphate has been omitted from the manurial programme the growth of the flax-fans is worse than on the untreated plots. Phosphatic manure with lime treatment is extremely important for the development of *Phormium tenax* on pakihi land. The use of potassic and nitrogenous manures, although helpful, is not nearly so important as the use of liberal quantities of phosphate.

Tree Plantations.

In a previous report mention has been made of the tests which are being conducted with different trees and shrubs to determine their value for shelter purposes on pakihi land. Eucalypts, both *E. rostrata* and *E. globulus*, have both made good growth. Of the pines, *Pinus banksiana* and *P. mariana* have done better than *Pinus insignis* and *P. maritima*. In regard to hedge plants, pampas, *Phormium tenax*, and pussy willows have made good headway, and fair results have been obtained with privet and prickly acacia. Escalonia and wattle did not survive the second year of the test.

T. Rigg, Officer in Charge Pakihi Investigations.

LEATHER AND PELT RESEARCH.

Advisory Committee: Messrs. C. Arlington, J. E. Astley, J. Garton, A. E. Lawry, W. Donovan, F. Johnson. Director of Research: Mr. P. White. Assistant: Mr. F. G. Caughley.

Leather Research.

The work of an industrial research association may be divided into two distinct classes—namely, fundamental research and the investigations of factory problems which arise in the works connected with the association. Fundamental research in itself does not appeal very much to the manufacturer, as his first requirements concern factory problems which arise from day to day. Fundamental knowledge on basic principles, however, has to be obtained if problems connected with these principles, as factory problems are, have to be solved satisfactorily.

During the year under review the work connected with industrial problems has, as in the past, had prior claim to any other work which was being carried out. A very close contact between the laboratory and tanneries has been maintained, with the result that the service side has claimed more attention than actual research.

In the time available research work has been carried out on processes connected with factory routine. No definite programme was followed, and this elasticity has resulted in the investigation of side-issues sometimes taking the place of what was originally the major issue.

Leaching of Bark.

The chief tanning-material used in New Zealand in the earlier stages of tanning is derived from ground wattle-bark. The leaching of this bark may be a very fruitful source of waste and requires careful control if loss is to be avoided.

Analyses of the original ground bark disclosed marked variations occurring throughout the consignments. These are to be expected, since all the bark cannot be of the same age, thickness, and from the best parts of the trees. On the other hand, some of the variations were larger than ought to exist where uniformity in processing is necessary. The results of the tests on spent bark have been to exercise better control of the leaching-process. At the same time, it was found out that some barks leach more readily than others, and that a tannin analysis of the original bark is not always a true criterion as to its actual value. One of the factors affecting the leaching-value is the degree of fineness to which the bark has been ground.

Wearing of Sole-leathers.

As in past years, there have been a few isolated cases of complaints about the failure of sole-leather to stand up to alleged reasonable wearing-conditions. The test mentioned in the last annual report—viz., the amount of soluble nitrogen present in the damaged sole — has shown that in practically all the cases examined the defect in the leather was caused by the action of excessive heat on wet leather.

The hot, dry summer has brought into prominence another problem connected with the deterioration of leather under wear—viz., effect of perspiration. It is well known that perspiration will rot leather and textiles under certain conditions. With leather this rotting is very evident on the insoles of shoes, especially when worn in conjunction with rubber soles. The rubber does not allow perspiration to pass through it, and consequently there is an accumulation in the leather insole. The rotting-effect of perspiration is very similar to the damage caused by heat and acids. One difference, which though not established definitely, appears to be the elimination of the water solubles. Whether the water solubles present in leather are fixed on the hide fibres or rendered insoluble by oxidation is the object of investigations at present being carried out.

Oiling of Sole-leather.

The major research investigation carried out during the year has been on the action of oiling wet sole-leather in its relation to the colour of the dry leather.

Colour in sole-leather is a very important quality not only as regards its selling-value, but also as indicating freedom from crackiness and also good scouring-qualities in the boot-factory.

The results obtained in this investigation were—

(1) Bad colour of sole-leather is partly due to a surface effect of a continuous layer of solid tannin material on the grain surface.
(2) Oiling tends to break this surface effect, and so improves the colour.
(3) Oiling by breaking the surface effect also tends to reduce crackiness.
(4) The application of oil tends to drive the water solubles into the leather and thus reduces the amount on the surface.
(5) The application of oil coats the leather fibrils and fibres with oil and thus prevents the water solubles coming to the surface.
(6) On properly oiled leather, drying at first takes place at the surface and then gradually the drying surface penetrates into the leather.

General.

The circulation of monthly letters describing the research carried out in New Zealand and abroad, and other topics of interest, has been maintained.

Lectures have been broadcasted to farmers and to boot-repairers dealing with leather, its qualities, limitations, and its proper use and treatment.

The usual routine-work of checking factory-control, methods of manufacture, &c., has been performed and has been of valuable assistance in the investigation of factory problems.

Pelt Research.

The work on pelt research has been divided into two parts—viz., the work in the laboratory, and the application of the results obtained to actual practice in the form of trial shipments.

In the laboratory, investigations were carried out on the pickling process and the effect of storage under different conditions on pickled pelts. The established standards of a well-cured pelt are based on the observations carried out over a number of years. On the other hand, sometimes pelts which apparently do not conform to these standards after long storage and transhipment are found to be still in good condition. The results of the investigation showed that conditions of storage may affect the results of the chemical analysis of the stored pelt. If a true interpretation of the condition of the pelt and the process used in curing it originally is to be obtained, then the standards must be extended to take into consideration the chemical effects of storage.

The deliming or, as it is sometimes erroneously called, the "bating process" was investigated. The importance of this process, its effect on the fibre-structure of the skin, was definitely established. The application of the results obtained has demonstrated conclusively that improper deliming may be the cause of serious defects in the skin, and has been, in the past, one of the major faults of processing.

The value of industrial research is generally assessed on the effects obtained by the application of laboratory results to actual factory processes. This application of theory to practice is sometimes more difficult than the original laboratory investigation, requiring time, thought, and ingenuity to overcome the many practical difficulties and uncontrollable conditions in the factory.

As in past years, the sending of trial shipments of pickled pelts to England has been the method of the Research Association in applying laboratory results to works practice. When sending these trial shipments, the assumption was made that by making each lot to consist of about four hundred skins the natural variations would be, to a great extent, eliminated.

The reports received from the London Committee on the trial shipments during the year appear to indicate that the above assumption was not justified. The season 1933–34 was remarkably early, and probably on this account the carcass matured at the expense of the skin. Whatever the reason, skins, on the whole, were below the average quality. The trial shipments were prepared at the usual time, but owing to the early season the selection of lambs would, of necessity, be very mixed. Consequently, large variations in the inherent quality of skins would be expected.

The reports of the English tanners, who again gave so freely of their time and work to the tanning of these trial lots, were not so conclusive as was expected. In spite of the care taken to control the processing of each trial lot, the natural variations in the lots nullified to some extent the results expected from the change in the processing under test.

In themselves the reports do not give clear-cut indications of the value of the changes tried. On the other hand, the results, when considered with those obtained in previous years, gave valuable confirmatory evidence that the results obtained in the laboratory were fundamentally correct.

The compilation of data over a number of years is absolutely essential if progress, established on a definite scientific basis, is to be made.

Great progress has been made in the past few years on the chemical and mechanical aspects of processing pelts. The time has now arrived that if further progress in this direction is to be made more knowledge must be obtained on the natural variations in the quality of the skins themselves.

During the present year efforts will be made to investigate the effects on the skin of the age and the length of the wool when the animal is slaughtered.

The London Committee has given valuable assistance in the work being carried out, and it is desired to place on record an appreciation of their help during the year.

The grant from the Empire Marketing Board has enabled the work to be maintained, and an acknowledgment of this help is gratefully recorded.

FRUIT RESEARCH.

Advisory Committee: Mr. A. H. Cockayne (Chairman), Messrs. T. Rigg, W. J. Moffatt, T. C. Brash, W. Benzies, A. M. Robertson, R. Paynter, J. A. Campbell, F. S. Pope, Dr. G. H. Cunningham. F. R. Callaghan, Secretary.

General.

The Fruit Research programme has continued as a co-ordinated activity, the participating bodies being Plant Research Station, Cawthron Institute, Horticulture Division of the Department of Agriculture, and the Department of Scientific and Industrial Research. The Dominion Laboratory, Geological Survey (Soil Branch), and the Meteorological Office have also undertaken investigations associated with Fruit Research.

Overseas co-operation has also been effected with the Low Temperature Research Station, the Imperial Bureau of Fruit Production, the East Malling Fruit Research Station, and with the Australian Council of Scientific and Industrial Research.

The Fruit Cold Storage Committee has continued to deal with all problems affecting the handling, storage, and transport of fruit. The Fruit Research Workers' Committee has met periodically to consider details of the investigations inaugurated and to examine the progress made in each.

The field-work connected with the investigations is carried out at (1) the research orchard of 72 acres, at Appleby, Nelson, 29 acres of which are planted in full-bearing trees; (2) the Cawthron Institute Orchards, Nelson; (3) the Tiritea area attached to the Plant Research Station, Palmerston North; and in (4) a series of selected orchards distributed through the various fruitgrowing districts of the Dominion.

The work has been greatly facilitated by the ready assistance rendered on numerous occasions by the New Zealand Fruit Export Control Board, the New Zealand Fruitgrowers' Federation, and the shipping companies operating in New Zealand waters.

1. Orchard.

The whole of the planted area of the orchard is in full utilization for the conduct of manurial, spray, and cultural trials, and is available for the field studies arranged by any of the workers engaged on various researches. Very detailed records of tree-growth, yield, leafage, blossom, &c., are regularly made so that the closest watch may be maintained upon any changes which appear. All the trial areas have been arranged in accordance with the best methods of experimental layout and are designed to reduce experimental error to a minimum.

In the 1934 season the yield of fruit reached a maximum figure of 10,953 bushel cases, 10,333 being available for export. In 1935 there was a marked drop in yield to 4,785 bushel cases, 3,134 being exported. The orchard shows to a marked degree the characteristics of alternate year cropping, as will be seen from examination of the following seasonal yields; 1931, 4,600 cases; 1932, 7,620 cases; 1933, 4,233 cases; 1934, 10,950 cases; 1935, 4,785 cases.

Weather conditions during the present season were quite favourable to the production of a good crop and do not account for the big drop in yield which occurred. The problem of biennial bearing is now being made the subject of a major research because of the importance it has as regards marketing and also wastage and deterioration in fruit-quality.

During the season the position in regard to insect and fungous pests at the orchard remained normal. Woolly aphis spread to such an extent in Cox's and Dunn's that spray applications were resorted to owing to the lateness with which the parasite *aphelinus mali* appeared. Black-spot was slightly more prevalent in the Delicious variety, but not noticeably so in the case of the other varieties. Botrytis-rot was not conspicuous owing to the dry weather conditions of the early summer months.

Manurial Experiments and Associated Cold-storage Trials.

At the present time, two years and a half from the commencement of applications on the main blocks, responses can be recorded from nitrogen and from potash treatments. Phosphates have yet given no indication of being a limiting factor in the production and properties of either wood, foliage, or fruit. Nitrogen has continued to give striking growth and foliage differences, and in two instances has given a crop-weight increase. During the present period potash has given for the first time an indication of effect on both tree and fruit.

All varieties other than Jonathan and Sturmer are carrying a light crop this year, following the very heavy crop of 1934, and, consequently, the foliage is, in general, looking remarkably well. Notable exceptions to this are those untreated Cox's, Dunn's, Delicious, and Sturmer trees that happen to be situated on poor clay ridges.

Nitrogen has been applied in the form of ammonium sulphate, potash as the sulphate, and the phosphorus as 44–46 per cent. superphosphate.

Following are notes on the 1934 crop and the 1934–35 growing-season. Orchard and cold-storage findings are all grouped together under variety headings for the sake of brevity.

Cox's Orange.—(*a*) The vegetative response to nitrogen is now becoming evident even on the big trees that are in a relatively favourable environment on the lower slopes. Untreated trees are beginning to show the effect of their continued starvation by a diminution of vigour.

(*b*) Inclusion of potash in the manurial programme has minimized the incidence of "die-back," or, more strictly, sour-sap, which appeared in many trees following the wet winter and spring of 1934. Potash-treated trees have since made almost complete recovery.

(*c*) Fruit from trees under heavy potash treatment developed more bitter-pit in storage, but until the evidence of subsequent years is available significance is not attached to the result.

(*d*) Even in a year of high yield the use of a nitrogen dressing as heavy as 3 lb. per tree may adversely affect the storage-quality of the fruit. This would appear to take place when marked growth stimulus has been produced.

Dunn's Favourite.—(*a*) The response to nitrogen can now be seen even on the initially vigorous trees.

(*b*) There has been an indication of a small decrease in the amount of skin-cracking by increase of the nitrogen application to 4 lb. per tree, but emphasis is not yet placed on this result.

(*c*) Ammonium sulphate at the rate of 4 lb. per tree gave rise to an increase in the susceptibility to storage bitter-pit, to skin mottling, and particularly to fungous disease. In the year of heavy crop, breakdown-susceptibility was not appreciably increased by this high nitrogen level. Over a short storage period of two months no unfavourable character was noted in the fruit from the 4 lb. plots; in this respect there is a marked difference between the "on" and the "off" years.

Jonathan.—(*a*) The progressive growth responses induced by 2 lb. and 4 lb. ammonium sulphate were practically levelled out by the heavy crop of the 1934 season, but, on the other hand, definite crop-increases were secured.

(*b*) The colour-grading of the fruit was not excessively depreciated by the 2 lb. rate of application of nitrogen, but was by the 4 lb. rate.

(*c*) Fruit of the heavy crop kept almost entirely free from breakdown in storage, irrespective of treatment. There was some incidence of Jonathan-spot, and this was more severe on the fruit from trees receiving high rate of nitrogen application.

(*d*) Fruit from trees receiving a heavy potash application kept greener and firmer in cold storage than the no-potash control fruit.

Delicious.—(*a*) The growth-response to nitrogen remains the chief feature of the tests on this variety.

(*b*) Storage-quality of the fruit continues to be unaffected by any of the treatments.

Sturmer.—(*a*) Trees under complete treatment are now in better condition than any of those under partial treatments.

(*b*) With complete treatment and, to a less extent, with phosphate and nitrogen significant crop-increases have been secured.

(*c*) Fruit from complete-treated plots has, like untreated fruit, kept almost free from breakdown in storage.

(*d*) As with Dunn's, there was more skin-mottling where nitrogen was included in the treatment.

Spraying-experiments.

Expenditure on this work has been very light this season as only oil-sprays for red-mite control have been carried out during the year. The plot of eighty-eight Delicious trees set apart for the black-spot investigations by Dr. K. M. Curtis, Mycologist to the Cawthron Institute, were again reserved for the continuation of this work and assistance rendered in connection with the spraying of the trees and treatment of the ground-surface.

Grafting-experiments.

Three trees of Sturmers were grafted over to Dunn's in the spring of the year for observational purposes on the refurnishing system, and have made satisfactory growth. Several trees which were grafted over in the 1932 season to Delicious and Cox's Orange have been left with leaders unpruned for comparison with others pruned in the orthodox manner, and have been an object of interest to visiting orchardists.

Testing of Varieties.

(*a*) *Crimson Cox's Orange.*—This variety was obtained from England by the Department of Agriculture and planted on the Research Orchard. The fruit has been under observation for three seasons, but so far its quality and appearance does not justify its inclusion in the list of recommendations for future planting or reworking on established trees.

(*b*) *Granny Smith.*—Scions of this variety procured from Victoria were grafted on to a Northern Spy tree at the Research Orchard for comparison with other trees of this variety growing in the district. So far there appears to be no difference in growth or appearance of the fruit. The apples so far produced on this tree are very subject to bitter-pit.

(*c*) *Hazel Nuts.*—Fourteen trees of variety *Corylus maxima* were planted in 1933 season for testing-purposes. Several of these have died out and others have made poor growth. The land is probably quite unsuitable for nuts, and failure to succeed here is no doubt due to this cause.

(*d*) *Pear-tree* (Pyrus calleryana).—A tree of this variety was planted this season for testing-purposes and has satisfactorily established and making fair progress.

Meteorological Station.

Weather reports are regularly taken and despatched to the Meteorological Office, Wellington. These records, in the course of time, will become of distinct value in tracing the relations existing between weather conditions and various aspects of fruit-production.

Improvements.

Additional storage for implements has been provided adjacent to the packing-shed, while a beginning has been made to fence the orchard with wire netting as proof against rabbits and hares, which have caused serious bark damage to a number of trees.

Nursery.

The 600 trees established on East Malling stocks in the nursery have reached the stage for transplanting, and in consequence some ninety trees have been planted out at the orchard and the remainder have been handed over to the Cawthron Institute and the Horticultural Division for trial elsewhere.

2. Botanical Investigations.

Stocks.—(*a*) Apples: In order to ascertain the suitability of East Malling stocks for New Zealand conditions, and to compare their performance with that of Northern Spy stocks, there have been established at the Plant Research Station and in the orchard districts of Auckland, Hastings, Motueka, Dunedin, and Alexandra some two hundred trees comprising Delicious, Cox's, Jonathan, Sturmer, and Statesman worked on the above-mentioned stocks. Growth records are being kept in all districts. A further supply of six hundred apple stocks have this year been budded with Cox's, Delicious, and Jonathan.

(*b*) Plums: Monarch, Grand Duke, Kirke's, and Yellow Magnum Bonum varieties have been budded for trial on to five types of stocks received from East Malling.

Northern Spy Stocks.—In order to test out the different influences exerted by stocks of Northern Spy raised from clones and from root-cuttings respectively upon scions grafted thereon a number of Jonathan scions have been established on the two classes of stocks.

Strains of Apple and Stone Fruit Varieties.—In order to improve the Delicious apple orchard instructors throughout New Zealand have selected bud wood from promising strains, and a large number of these selections have been worked on the quickly maturing East Malling strain IX, so that the earliest possible indication will be received of their value. In view of the probability that extensive reworking of apple orchards may be necessary in the near future this work is of the utmost importance. Strain-selections have also been extended to Cox's Orange apples and to two apricot and three peach varieties.

Filberts.—A further supply of 114 trees of the species *Corylus maxima* propagated from Cadbury's original supply was distributed for trial in the fruitgrowing areas of New Zealand.

3. Entomology.

Woolly Aphis.—In the search for new stocks immune to woolly aphis, a test of Large's seedling stock showed that this was liable to attack. Counts of aphides affected by *aphelinus mali* in samples of woolly aphis received from all fruit districts are now being made. Winged aphides have been found parasitized and hence may play some part in the distribution of *aphelinus mali*. Inspections made during the season have not revealed that winged aphides play any part in the dispersal of woolly aphis.

Pear Midge.—Miscocyclops has been shown to parasitize pear midge to the extent of 20 per cent. of the first brood larvæ and 70 per cent. to 80 per cent. of the second brood in the Henderson district. In Nelson no parasitism occurred with the first brood, but some 30 per cent. of the second were affected.

Leaf-hopper.—Counts have been made of leaf-hopper populations in the Annesbrook orchards. In this season populations of thirty nymphs in the first brood and sixty nymphs per hundred leaves in the second brood did not produce any economic damage by destruction of leaf-tissue or by spotting of fruit. *Anagrus* parasitized some 70 per cent. to 80 per cent. of the winter and about 60 per cent. of the summer eggs of leaf-hopper.

Codling Moth.—Attempts have been made to establish two parasites, *Accogaster* spr. and *Phanerotoma* sp., but so far have not proved successful.

Bronze Beetle.—Flight-range studies of this pest have been attempted, but as yet a satisfactory technique has not been devised.

Leaf-roller.—A search is being made for parasites in leaf-roller, and a preliminary survey of the leaf-roller position in Central Otago has been undertaken with a view to further work being done during the infestation period next season. Two native moths are under suspicion as being responsible for the trouble caused to apricots and peaches in this district.

4. Mycology.

Fireblight.—In view of the reports from the United States of America that under certain climatic conditions the incidence of fireblight can be controlled to some extent by an application of bordeaux mixture at mid-blossoming period, this mixture was at a strength of 1–3–50 to Winter Cole pears in the Annesbrook Orchard belonging to the Cawthron Institute. This treatment did not produce scorching of blossoms or young fruits, nor was scorching visible on maturity. It would therefore appear that a weak bordeaux mixture can be safely utilized in fireblight-control tests on Winter Cole pears in the Nelson District.

Black-spot of Apple and Pear.—A fairly heavy black-spot infection which occurred in most parts of the Nelson District was caused by heavy ascospores discharge during late September and up to mid-October. An examination of twigs of Cox's Orange trees that were known last season to have been heavily infected with black-spot were examined in order to ascertain if these were likely to provide sources of infection, but none were found. This work was done because reports from England indicate that twig-infection plays an important part in the propagation of black-spot in orchards. Trials carried out with lime-sulphur, caustic-soda, and bleaching-powder sprays on dead leaves infected with black-spot ascospores showed that lime-sulphur and bleaching-powder sprays brought about some reduction in the heavy infection of spotted apples.

Mouldy Core.—A survey of the fungi responsible for mouldy core is revealed over thirty different spheres which are present in the Nelson District, and of these about half a dozen appeared to be responsible for the initial stages of the disease. This half-dozen comprises *Fusarium*, *Alternaria*, *Coniothyrium*, *Phoma*, and *Pestalozzia*. It would appear that these diseases make their inroads into soft-flesh apples, such as the Delicious variety, more rapidly than they do into those of the firmer texture.

5. Spraying-investigations.

Investigations have been carried out by Mr. G. G. Taylor on various aspects of spray application and its relationship to disease-control. During the past season he made a survey of the stationary spraying outfits in Hawke's Bay to ascertain the effects of pipe-size, pump-capacity, and reticulation on disease-control. The data collected showed that failure to combat disease is frequently due to faulty spraying-systems. Additionally, he investigated the effects of varying volume applications on the control of red-mite, codling moth, and black-spot. Using standard materials at normal dilutions he showed convincingly that much better control could be obtained simply by increasing the volume applied. The results were checked by chemical estimations of the amount of spray deposited on leaves and fruit by different treatments (all analytical work being undertaken by Mr. P. J. Clark, of the Dominion Laboratory). These showed that there was a definite correlated increase in spray-deposit as spray-volume was increased. Where casein spreader had been added to the spray the reverse obtained, for the run-off was so great that the deposit tended to decrease with applications in excess of 3 gallons per minute. Further experiments planned to test the efficacy of new compounds as controllants of brown-rot gave inconclusive results owing to variable infection.

In addition to the analysis of spray-deposits on leaf and fruit samples, Mr. Clark has analysed samples of various nicotines, pyrethrums, spreaders, wetters, &c. The object of this work is the ultimate standardization of those spray materials which at present cannot be recommended on account of this variability.

6. Manurial Trials.

Manurial trials are carried in three sections, at (1) the Research Orchard, Appleby; (2) in the Cawthron Institute orchards; and (3) in private orchards throughout the fruitgrowing districts. These orchards are selected by the Horticulture Division of the Department of Agriculture.

The report of the trials at the Research Orchard appear in a previous section of this report.

Cawthron Institute.

The manurial experiments include fertilizer trials on Jonathans at Upper Moutere, Cox's Orange at Waimea West, and Sturmer and Dougherty apples at the Annesbrook Orchard of the Institute. Yield data for the 1934–35 crop are not available for the Annesbrook Orchard, but in the case of the Jonathan experiments at Upper Moutere even more definite results than last year have been obtained.

The yield data for the season just concluded show increases of over 100 per cent. in the case of trees receiving a complete manure of 4 lb. superphosphate, 1 lb. muriate of potash, and 3 lb. of either dried blood or ammonium sulphate. On this poor type of soil the use of 3 lb. of nitrogenous fertilizer along with superphosphate and potash has given higher yields than corresponding mixtures containing only 1 lb. of nitrogenous fertilizer. The use of nitrogenous manures at the rate of 3 lb. per tree without phosphate and potash show after six years' treatment an increase of 50 per cent. over the untreated plots, but a big reduction over plots receiving complete treatment. It is interesting to note that on this plot receiving nitrogen only the trees frequently show poor growth and the fruit is small and is affected with much cracking and russeting. The colour of the fruit on this plot is extremely poor. The highest yields are now being obtained from the plots which have received, in addition to nitrogen and phosphate, very liberal treatment with potassic manures. On these plots, where 4 lb. of either sulphate of potash or muriate of potash per tree per annum have been given over a period of years, growth and yield of fruit are now much better than that associated with similar plots receiving only 1 lb. of potassic manure per tree per annum. Yield data from this last season show a difference of approximately 20 lb. of fruit

per tree in favour of the large dressing of potassic manure. The beneficial effect of heavy potassic manuring on this poor type of soil has been confirmed by a supplementary experiment where very large amounts of potassic manure were dug in round certain trees on another block last winter. In connection with the Jonathan experiments fruit from the different plots was graded for colour, size, and russeting. In regard to colour, the best result was obtained on the untreated block, but blocks treated with dried blood plus phosphate and potash were also very good. From the point of view of colour, the plot receiving nitrogen only was easily the worst.

In regard to size of fruit, the untreated block and the block receiving nitrogen only had 30 per cent. to 35 per cent. of the crop of $2\frac{1}{4}$ in. or under. In regard to russet, the plot receiving nitrogen only was very badly affected, but was followed fairly closely by the untreated plot.

Co-operative Trials.

Sixty-seven co-operative trials arranged through the Horticultural Division and treated in the various fruitgrowing districts of the Dominion have been continued. The trials have included treatment with N.P.K. and lime alone and in association in various groupings. Though yield-records are being taken with certain of the trials, most have been assessed by general observations of visual response.

Soil-injection Trials.

Owing to the poor response generally attending surface applications of phosphate and potash manures and to the reported success attending soil-injection treatments overseas, five trials in the Auckland, Palmerston North, Motueka, Nelson, and Marlborough districts have been commenced in which solutions of superphosphates and potash have been injected into the soil at forty-eight points round the experimental trees. A lance injector has been used and the fertilizer placed at a depth of 10 in. to 15 in.

Results, by Districts, of Manurial Trials.

Auckland District.—Apples: One experiment classified has now been under yield measurement for five years. In the 1933–34 season all treatments, including phosphate, were higher in yield than no-manure plots by about 25 per cent., and although these differences were barely significant statistically the trend in favour of these treatments in this and previous seasons suggests that such differences are real.

In two out of three experiments the lime effect would appear to be quite definite. Part at least of the effect is no doubt due to the encouragement of the growth of legumes, notably *Lotus spp.*, and the resulting additional nitrogen. Sulphate of ammonia has caused an improvement in colour and density of foliage in the other experiments.

Peaches: In one experiment the no-manure plot is very inferior to the remainder, while the plots treated with nitrogen are the most vigorous.

Tauranga District.—Lemons: Nitrogen has been effective in all experiments in this district.

In one experiment the yields of uncured fruit from phosphate, phosphate plus nitrogen, phosphate plus potash, and phosphate plus potash plus nitrogen are now 23, 38, 32, and 44 per cent. greater than no manure. Severe frost injury to the foliage and fruit of all plots not receiving nitrogen occurred during the past winter, and while the super and super plus potash plots have recovered slightly the trees in the no-manure plots are in very backward condition.

In another trial in which lime is compared with no lime, lime continues to be effective, and since the commencement of the experiment in 1930 has yielded 71 lb. of uncured fruit per tree more than the unlimed plots.

Roxburgh-Ettrick (Otago).—Apples: In the 1933–34 season no significant differences between yields or in the condition of the trees under various treatments were recorded.

In five experiments there has been a general improvement in vigour and colour of foliage on plots treated with nitrogen. In one of these trials there has also been a response to lime.

Peaches: A slight improvement allegedly due to potash and also benefit from nitrogen has been obtained in one experiment.

Apricots: Two experiments both show a nitrogen response. In the trial with mature trees the crop on the nitrogen plots was later in maturing than the fruit on the other plots. This was an advantage to the grower as it extended the picking-period in a season when apricots ripened rapidly.

Central Otago.—Apples: In experiments the effect of nitrogen applications has been noticeable. The nitrogen plots were distinctly earlier in the opening of the flower-buds. On the other hand, lime appeared to retard the opening of the flower-buds and the blossoming of the trees.

Peaches: Nitrogen continues to be effective in improving the foliage and growth in the two experiments. The maturing of the crops was delayed. This was of benefit to the growers in two ways—(1) The spread of the picking-period in a season when stone fruits ripened quickly, and (2) the later fruit realized a better price.

One of these growers, as an outcome of the results of the trial in his orchard two seasons ago, adopted the practice of treating a portion of other stone-fruit trees with nitrogen. In these seasons, while other growers were suffering a loss of fruit due to over-ripeness and poor prices, this orchardist picked his crop with ease and obtained satisfactory prices.

Apricots: In the three experiments nitrogen has again proved effective in inducing vigour to the trees on which it has been applied. The marked effect in lessening frost injury was again manifest on the nitrogen-treated trees last winter. In one trial in which varying quantities of nitrogen was used the degree of effect on maturity was quite marked—the larger the amount of nitrogen the later the maturity and generally the larger the size of the fruit.

General Comments.

The most outstanding features of the trials have been the marked effect of nitrogen in the general stimulation of the trees, the improvement in the colour and size of the foliage, particularly on soils low in organic matter, and the effect on the rate of maturing of stone-fruits in Otago. The ability of trees receiving nitrogen to withstand frost injury was exemplified last winter in Central Otago and also in the lemon-manuring trial at Tauranga. Apart from Hawke's Bay, where up to the present time no responses have been noted, such responses to nitrogen have occurred in all districts where experiments have been laid down.

Phosphates appear to have produced a slight improvement over no-manure in most districts. In one experiment under yield-measurement in the Auckland Province the phosphate response borders on significance.

There is no observable or measurable effect from potash used in conjunction with phosphate, with the possible exception of one experiment at Roxburgh. Potash used with phosphate and nitrogen has given slight evidence of benefit in a few experiments.

In some experiments in Auckland the effect from lime would appear to be quite definite. No results have yet been secured from the trials in which broadcast applications of fertilizers are compared with those concentrated round the tree or from the experiments in which the efficacy of injecting fertilizers in solution into the soil is under trial.

Donation of Fertilizers.

The potash and sulphate of ammonia were donated by Pacific Potash, Ltd., and Imperial Chemical Industries, Ltd., respectively, during the past season. These donations have materially assisted the programme of work to be carried out.

7. Physiological Diseases.

Owing to the growing severity of the group of physiological diseases, known under the names of bitter-pit, corky-pit, internal cork, corky-core, and crinkle, a special request was made to have these diseases specially investigated. A special sub-committee of the Fruit Research Workers' Committee reviewed the position as it was known to exist overseas and made use of the data gathered in a partial survey which had been conducted by a member of the staff of the Research Orchard in the previous season. The assistance of the Imperial Bureau of Fruit Production was also enlisted, and this resulted in that body preparing a complete bibliography of references to bitter-pit. This account of everything that had been done elsewhere in the world was most valuable and is illustrative of the great practical importance attaching to co-operation in research on an Imperial basis. With all the available knowledge assembled the committee prepared a programme of investigations in the hope that by extensive methods some indication might appear for a line of concentrated attack upon a problem which appeared highly complex and which had previously resisted all attempts at its explanation or its solution. This programme was put into operation during the winter of 1934, certain members of the staff of the Research Orchard and Cawthron Institute being seconded specially to conduct the trials which had been decided upon.

Certain orchards in the Braeburn district, where the incidence of corky-pit was known to be severe, were selected for various treatments under the following headings: (1) Physical modification of the soil; (2) root and branch prunings and tree girdling; (3) leaf-reduction; (4) hypodermic injection of some sixteen chemical solutions into tree tissues; (5) control of soil-moisture. The field-work was closely associated throughout with laboratory investigations.

In March, 1935, Mr. J. D. Atkinson, who was in charge of the Braeburn field experiments, reporting on the tree-injection treatments, stated that none of these had proved effective with the exception that in the only three trees which had been treated with boracic acid the pit had been practically eliminated. All the fruit on the trial trees was cut and examined, and while the percentage of affected fruit ranged up to 100 per cent., that growing on the only trees treated with boracic acid was reduced to a maximum of 3 per cent.*

Soil-investigations undertaken by the Cawthron Institute indicated that corky-pit was most severe on soils with a heavy, tightly-packed layer of clay near the surface under which there exists a more open subsoil usually of a sandy loam texture. The water-table in one orchard where severe pitting occurred rose close to the surface in winter, causing destruction of the fibrous roots and root-hairs. In all cases examined the relatively small fibrous root-system of badly affected trees was noteworthy. Otherwise the root-systems of unhealthy trees showed little difference from those which were unaffected with the disease.

Soil-moisture determinations made regularly in the 6 in. to 12 in. layer indicated that little difference occurred in the moisture-status of healthy and unhealthy areas. Similar investigation of the moisture-content of Jonathan apples from healthy and unhealthy areas yielded no material differences. In connection with the fruit analyses made in these trials it was revealed that towards the end of the season only small amounts of nitrogen and ash are absorbed.

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*J. D. Atkinson: "Progress Report on the Investigation of Corky-pit in Apples." N.Z. Jour. of Sci. & Tech., XVI, 5 pp., 316–319; March, 1935.

A most important result was the finding by Dr. H. O. Askew, of the Cawthron Institute, that analyses of fruit and leaves of trees carrying pitted and sound apples showed that the boron-content of that from the healthy trees was some three times as great as that from the affected trees, thus helping in the confirmation of the field trials which previously indicated the possible association of corky-pit with a boron-deficiency in the soil or tree. A report of the chemical work carried out by Dr. H. O. Askew will be published shortly in the *Journal of Science and Technology.*

Surveys of the incidence of corky-pit in the 1934–35 season have shown that its prevalence was much less general than in the previous year, and there is a possible connection between this disease and the size of the crop in that it appears worst in the heavy crop years. None of the apple varieties grown in the Nelson District appear to be immune from the trouble, and three varieties of pears have been noted as also affected with corky-pit. The grafting of healthy trees on to affected stocks has not given relief. The seriousness of the disease is indicated by the fact that some two hundred and eighty trees in the area surveyed have been pulled out and upwards of seven thousand reworked because the crops in the preceding years were worthless.

Plans have been put into operation for further trials to ascertain to what extent boron treatments may be made effective as remedies for corky-pit.

FRUIT COLD-STORAGE RESEARCH.

Advisory Committee: Messrs. J. A. Campbell (Chairman), R. Sutherland, W. Benzies, F. W. Grainger, T. Rigg, H. G. Apsey, L. W. Tiller, A. M. Robertson, Dr. M. A. F. Barnett, and F. R. Callaghan.

The programme of fruit cold storage has been continued during the year, the work being done in cool-stores in Wellington, Nelson, and aboard selected transporting vessels. The co-operation of the shipping companies, the Cambridge Low Temperature Research Station, and the Horticulture Division has played a very important part in the conduct of the investigations. The assistance of the New Zealand Dairy Produce Board in granting the loan of its distance-recording thermometer was much appreciated.

Transport Trials.

Dunnage, Tower System.—The trial of the Tower system of stowage as devised by the Cambridge Low Temperature Research Station, which was arranged aboard the s.s. "Nebraska," proved that this system was quite satisfactory for adoption in lower holds. The trial fruit turned out in good condition on arrival in London, and the temperature-distribution throughout the cargo of fruit-cases was generally satisfactory. Had fuller use been made of the side-grids it is considered that a more rapid reduction in temperature to less than 40° F. would have been secured. The "Nebraska" trial showed for the first time the value of the Tower system in an actual ship's hold, and further trials are being arranged to ascertain its use under other conditions.

Soil Types and Wastage.—Trials with Cox's showed that those grown on clay loam soils were affected with wastage to a greater extent than those from sandy loams. Cox's from Hawke's Bay developed less wastage in cold storage than those from any other district, while Motueka fruit suffered worst as regards fungal wastage. These results, in general, confirm those arising out of similar trials in previous seasons. With the Jonathans the amount of wastage was so small as did not permit of any conclusions being drawn as to the influence of soil type or district upon keeping-quality.

Wraps and Wastage.—The value of the one-piece all-round wrap in reducing bruising was demonstrated in trials using all types of wraps. The influence of wraps on other causes of wastage showed that no variation in effect was apparent, no matter at what stage of maturity picking took place. The Jonathans used in the trial kept very well, and the total amount of wastage was negligible.

Maturity.—Cox's and Jonathans picked at early mid-season and late-season intervals were tested for keeping-quality. In the Cox's bitter-pit was prevalent in the early-season fruit, while the late pickings were soft and about to collapse at the examination dates after cold storage for six weeks. Jonathans kept so well at all stages of maturity that no conclusions could be drawn from the experimental fruit.

Wraps and Jonathan Scald.—In view of the large wastage from scald occurring in commercial consignments in two previous seasons the all-round wrap was held suspect, and further trials were arranged to test this wrap. The trials were very comprehensive, and Jonathans stored with all-round wraps showed no signs of scald-infection. Two years' investigations therefore indicate that the causal factor of Jonathan scald must be sought elsewhere than in the all-round wrap.

Cox's—Transport Temperatures.—Heavy losses from internal breakdown being characteristic of Cox's shipped overseas in 1932 and 1933, temperature storage trials were arranged with apples of counts 216 and 180. The trial showed that Cox's held at 36° to 38° F. showed less wastage than those maintained at 33° to 35° F., and confirmed the results secured in the previous year, which also were in favour of the higher temperature.

Influence of Irrigation on Keeping-quality.—Samples of Cox's, Delicious, Dunn's, and Sturmers grown in Marlborough under irrigated and non-irrigated conditions were subjected to trial. The sprinkler-system of irrigation was employed and did not in any way affect the keeping quality of the fruit.

SOIL SURVEY.—FIFTH ANNUAL REPORT.

During the year soil surveys were continued in the Waipa County, and a start made on a detailed survey of Levels Plain in South Canterbury.

The field-work in the Waipa County was carried out by Dr. L. I. Grange and Mr. N. H. Taylor, assisted by field hands subsidized by the Unemployment Board. This survey, which has been in progress for three years now, is nearly completed. Work in the county will cease at the end of October.

Dr. Grange mapped for the Public Works Department the soil types on Levels Plain, and Mr. K. S. Birrell is now locating the correct boundaries of the types. He visited Southland with Dr. J. K. Dixon to examine the soil type on which an anæmic sickness in lambs develops. He also accompanied Mr. F. R. Callaghan through the orchard districts of Central Otago for the purpose of inspecting the soil types of that district.

At the Cawthron Institute routine analyses of the soils of Ashburton and Western Taranaki have been carried out.

FIELD-WORK ON SOILS OF LEVELS PLAIN.

(By L. I. Grange.)

The Public Works Department, having collected considerable engineering data on the irrigation of Levels Plain, requested that a soil survey be made, in order to find out whether irrigation was practical from the soil point of view and, if there were no difficulties, to get a basis for experiments to determine the duty of water for each farm. A general mapping-out of the soil types was commenced on 14th February and completed a month later.

Levels Plain, near Temuka, South Canterbury, is a triangular-shaped area stretching for seven miles south-west along the coast and extending inland a distance of seven miles and a half, its width at the farthest point inland being less than one mile. Its northern boundary is the Opihi River and its north-western edge is the Timaru Downs. Altogether it covers about 19,000 acres. The plain rises from sea-level at the coast to a height of 160 ft. at its apex. It has been built up by the Opihi River, which rises in the foothills of the Southern Alps. The surface deposits are chiefly silt loams, ranging in thickness from less than a foot to more than 4 ft. Underlying these fine-textured beds are closely-packed gravels with a matrix of coarse sand. The river is entrenched less than 10 ft. in the plain and has a flood-plain, on an average not more than 20 chains wide. On the coastal margin there is a narrow shingle barrier, behind which the land is at or very close to sea-level.

The average annual rainfall is between 22 in. and 23 in., and there is slightly more rain in December and January than in other months. Originally the vegetation was matagauri scrub, tussock, and small grasses, except on the narrow coastal strip, where it was, and still is, vegetation tolerant of saline conditions.

The parent material of the soil is predominantly derived from greywacke. The underlying gravels and the pebbles occurring in the silt loam are all greywacke.

The silt loam and other soil material covering the plain are thought to have been deposited by the Opihi River and, to a small extent, by wet-weather creeks from the downs. This is in contrast with the deposits on the plain of the Ashburton County, which are mainly loess. The Levels deposits are classed as water-sorted because the depth of silt loam is far from being regular. Areas of uniform depth run in fairly narrow strips.

The soils are divided tentatively into four series—Levels, Arowhenua, Kereta, and Washdyke. The soils of the Arowhenua Series are younger in age than those of the Levels. Both are well drained. Those of the Kereta Series are meadow soils, and the soils of the Washdyke Series are saline. The soils of the Opihi flood-plain are omitted from the classification as they will not be irrigated and much more time would be required to map the rapid changes in texture.

The Levels Series covers an area as great as that of all the other series combined. It is divided into types depending mainly on texture, the types being Levels silt loam, silt loam (somewhat sandy), moderately stony silt loam, and stony silt loams. The silt loam (3,500 acres) forms a continuous belt on the southern side of the plain from its head to half a mile or so west of the Christchurch–Dunedin Railway. A profile on it shows:—

8 in. dark-grey silt loam;
3 in. mottled dark-grey and yellowish-brown silt loam:
On compact yellowish-brown silt loam.

The total depth of soil and subsoil is 18 in.; in many places it is more than 3 ft. The Levels stony silt loam (4,500 acres), occupying, roughly, the middle of the plain, extends from near the head of the plain to a distance below the railway. A profile is:—

8 in. dark-grey stony silt loam;
3 in. mottled dark-grey and yellowish-brown silt loam;
On gravel.

The depth to the gravel is not regular. In the gravel-pits depths ranging from 6 in. to 15 in. were observed. From numerous borings the average was placed at 10 in. The coarse sand fraction is higher than in the widespread silt loam; an average sample contains 15 per cent., whereas in the ordinary silt loam it is in some examples less than 1 per cent. In a few small areas not yet mapped the average depth is only 9 in. and the coarse sand fraction is more than 20 per cent., the texture being that of a stony sandy loam. Stones, generally 1 in. or 2 in. in diameter, are everywhere abundant; in an average sample stones make up 36 per cent. of the total weight. The other types of the Levels Series are located in an old channel of a wet-weather creek in the vicinity of Pleasant Point. The channel extends from the top of the plain to within two miles of the coast, its average width being

about 25 chains. The types run in long narrow strips. Ranging in thickness from 18 in. to 36 in., this silt loam contains a good deal more sand than the widespread silt loam of this series. The moderately stony and stony silt loams average about 12 in. in total depth. Profiles similar to that described for the widespread silt loam are obtained on these types within the old channel.

The Arowhenua Series extends along the south side of Opihi River from the top of the plain to within a short distance of the coast. There are two main types within it—the Arowhenua silt loam type (5,600 acres) and the Arowhenua silts, sands, and stony sands (1,100 acres). The former has a profile almost identical with that on the widespread Levels silt loam. The silts, sands, &c., occur in an old channel of the Opihi, which leaves the river about half-way down the plain. No detailed mapping of them has yet been attempted, but it can be said that the silts are the most common, and in general the depths of soil and subsoil is 18 in. or more. The top soils are lighter in colour than those of the silt loam type.

It may well be asked why two series and not one are made of the types so far described. The reason is that the Levels soils have been derived from weathered loess and in some parts have lost their top soil by blowing, whereas the Arowhenua soils are derived from young undisturbed river deposits. The latter are the more fertile.

The Kereta Series includes the meadow soils lying parallel to the coast and at roughly between 10 ft. and 20 ft. above sea-level. Its seaward margin is about 25 chains from the coast. A profile is :—

6 in. dark-grey silt loam ;
On grey to cream silt loam, mottled yellow by iron compounds.

In the lower-lying parts the top soil is peaty. The total depth is mostly more than 3 ft. Even in the summer months the soil is moist owing to the high water-table. Later work may show that this series, because of differences in fertility, can be divided into two.

The Washdyke Series lies at the back of the narrow shingle ridge on the coast. A profile is :—

6 in. to 9 in. peaty black silt loam ;
On creamy-grey heavy silt loam.

The total depth is more than 3 ft. The area is flooded with salt water during storms, and consequently the soils contain salts. The salt-content is least at the northern end close to the mouth of the Opihi River, where the soil is well drained and not peaty. A 0 in. to 6 in. sample from here contained 0·056 per cent. of Cl. The vegetation on this series is *Selliera*, *Cotula*, *Plantago*, *Salicornia*, &c.

The soils to be irrigated are those of the Levels and Arowhenua Series ; the soils of the Kereta Series are low lying and moist, and those of the Washdyke are water-logged in places. Of the series which will be irrigated the Levels stony silt loam and silt loam and the Arowhenua silt loam types require most attention as they cover a much larger area than the other types. These soils cover a gently sloping surface except those types lying in the old channels.

The soils of both series offer no difficulties for irrigation. The soil and subsoil are sufficiently light to allow the downward movement of excess water into the gravels. On the Levels Series the conditions are somewhat similar to those at Seafield, where irrigation has been successfully practised. The question arises whether the seepage of water from races and the excess water of irrigation will raise the water-table in the soils of the Kereta Series. Mr. T. G. Beck, in charge of the engineering survey of the plain, has collected data and is the only investigator who can make an authoritative statement on this point. Analyses of the soils in the Ashburton County show that the amount of soluble salts in the soils are negligible, and these results will apply to Levels Plain. Experiments should soon be started to determine the field-capacity, permanent wilting-point, and interval between irrigation on the soil types.

The soil map will be a guide to fertilizer experiments. Tentatively it can be said that quantitative top-dressing experiments are needed on the Arowhenua silt loam and the Levels stony silt loam, as the laboratory workers report that the phosphate-content of the former is very good, and that of the latter type is decidedly low.

The writer is indebted to Mr. T. G. Beck, of the Public Works Department, for facilities to make the Levels survey.

FIELD-WORK ON SOILS OF WAIPA COUNTY.

(By L. I. Grange and N. H. Taylor.)

During the 1934–35 season the soils of the Paterangi and Te Rahu districts were mapped. The progress of the mapping was slow, as a good deal of time was spent in collecting data on the pastures of the main soil types and securing fairly regular samples for determination of their moisture-content. Attention was also given to the problem of subdivision of all the peaty and peat soils which had already been mapped.

With this report is included a soil map on a scale of 40 chains to the inch of the north-eastern part of Hamilton Survey District. The map is fairly typical of those of other parts of the country already prepared, except that the peat soils occupy in the published map an area well above the average. The soil-work has been compiled on a topographic map, which has been prepared in considerable detail. On a skeleton map, showing roads, rivers, and boundaries of farms, the topographic data was added, the most important for the soil-worker being the subdivisional fences of the farms. Soil boundaries have been located by boring in each paddock. Variations within the soil types, noted by appropriate letters on the field-sheets, are not copied on to the published map ; the agricultural experimentalist will have most use for these data and can obtain them from the field sheets.

Except for the peat soils, the descriptions of soil types given in the two previous annual reports apply to the soils mapped during the present season. Two additional types, described below, were established by subdividing the Rukuhia peats.

The Rukuhia type has been divided into :—

(1) Kaipaki loamy peat, sandy peat, peaty loam, and peaty sand.
(2) Te Rapa peaty sand and peaty loam.
(3) Rukuhia peat.

The Kaipaki and Te Rapa types occur on the margin of the main swamps and comprise the whole of the smaller swamps. Rukuhia peat occupies the central portion of Rukuhia and Whatawhata Road Swamps and part of the Moana Tua Tua Swamp.

(1) The Kaipaki type of soil covers a considerable area in the Kaipaki district, and with the Te Rapa type forms a belt about one mile and a half wide bordering the Rukuhia peats. On the margin of the Rukuhia Swamp the belt of the Kaipaki type is, in general, only about 20 chains wide, except in the arm about one mile and three-quarters long and one mile and a half wide east of Ngahinepouri, where the whole area is covered by Kaipaki and Te Rapa types, and the margin from Frankton to Koromatua Lake, where this type averages about 60 chains in width. Kaipaki soils are fairly extensive in the swamp extending west from Te Rapa. Forests at one time grew on these soils, kahikatea being abundant. The profile is :—

4 in. to 9 in. peaty loamy peat, sandy peat, &c. ;
On peaty loam or loamy peat.

Except in winter, the top soil to a depth of some 9 in. is dry and powdery, the structure somewhat resembling that of a sand, though crumb-structure shows in some of the more loamy soils of this type. The colour is usually a dark grey or dark brown. After repeated burnings the top soil to a depth of 4 in. to 9 in. is a red or cream sand or silt loam. The subsoil, brown in colour, has for a certain depth a nutty structure and is poorly consolidated ; cracks which have opened several inches are common.

(2) The Te Rapa type is best classed with the meadow soils. It occurs chiefly in the swamp at Te Rapa and at Kaipaki, lying generally between the Kaipaki soils and the dry land, and running in narrow strips through the Kaipaki soils. The vegetation on it was similar to that on the Kaipaki type. The profile is :—

9 in. dark-grey peaty sands or peaty sandy loam ;
On buff to light-brown loam or sand.

The topsoil, except in winter, is dry and powdery. Its subsoil in general dries out in summer, but, unlike the Kaipaki type, remains compact.

(3) In the Rukuhia Swamp the Rukuhia type of soil extends over a width of five miles and a total length of about seven miles. So far in the Moana Tua Tua Swamp only part of the area this soil covers has been mapped. On the Whatawhata Road Swamp it occupies an area one mile and a half by one mile. The total area of the Rukuhia type is much greater than that of the Kaipaki or Te Rapa types. The vegetation is chiefly manuka and rushes. A profile on the Rukuhia Swamp shows :—

1 in. grey sands ;
On fibrous brown peat.

A field examination of the peat suggests that rushes and manuka twigs are its principal constituents. On the Whatawhata Road the peat is much more compact than in other parts and is moderately difficult to cut with a spade. Detailed observations in the Kaipaki and Te Rapa types have been made because they are the soils on which, with the present knowledge of farm-management, most improvement in pasture can be made. The results of this work will be published at a later date.

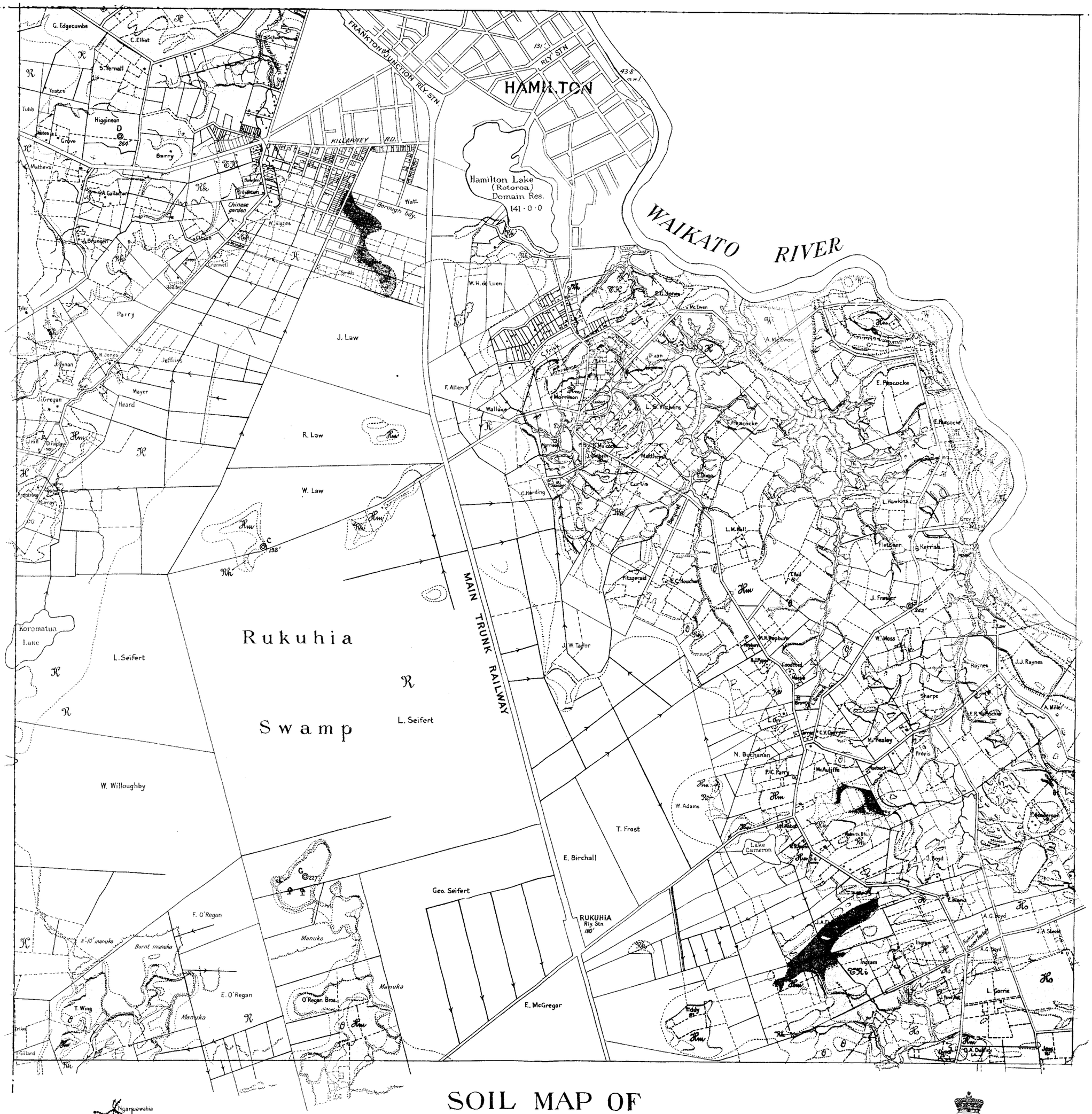
A series of moisture-determinations were made on the main soil types in the summer, autumn, and early winter of this season. The first series were collected on 10th December after a moderately long period of dry weather commencing on 22nd November. The second series were taken on 4th February ; only 2·88 in. of rain at Hamilton and 3·85 in. at Te Awamutu had fallen since the first series was collected. Later collections were made fortnightly, and in the intervals there were fairly copious falls of rain. At present only a few comments can be made, as the permanent wilting-point and field-capacity—necessary tie-points—have not yet been determined.

The following is a record of pasture conditions. Early in December the pastures on the Hamilton type were suffering from the dry conditions more than those of any other type. Those on the Horotiu type were just beginning to show the effects of dry weather, whereas Te Kowhai and Whatawhata pastures were browning slighly, and Ohaupo pastures were still green except on a few farms, where there was slight browning. On the 8th January both Hamilton and Horotiu pastures were very parched, and those of the Horotiu type now showed the effects of the dry weather more than the Hamilton pastures. The Te Kowhai and Ohaupo pastures were beginning to slump, but were definitely showing more green than Hamilton pastures. In the middle of February, after rain, the Hamilton and Horotiu pastures were still in poor condition, but in March all were green.

The moisture in the soils when the first series was collected was :—

Soil Type.	Percentage of Moisture (Oven-dry Basis).	Soil Type.	Percentage of Moisture.
Hamilton clay loam	13·8	Te Kowhai silt loam	16·7
Horotiu sandy loam	22·3	Whatawhata clay	21·1
Ohaupo silt loam	30·4	Kaipaki peaty loam	59·3

As the pastures on the Hamilton and Horotiu types were wilting the moisture figures must represent the permanent wilting-point or some figure below it. The Ohaupo pastures were showing slightly the effects of dry weather, so that the percentage 30·4 is not much above the wilting-point. The amount



Scale
MILES 10 5 0 10 MILES
Total area surveyed
Area covered by this sheet

SOIL MAP OF
PART OF HAMILTON S.D.
WAIPA COUNTY

SCALE
CHAINS 80 60 40 20 0 40 80 CHAINS (1 MILE)
KILOMETRE 1 ½ 0 1 2 KM
1 : 31680

J. HENDERSON
DIRECTOR.

Topography from Lands and Survey Dept. maps
Additional surveys by topographical staff of the Soil Survey
Soils by L. I. Grange, N. H. Taylor and W. M. Jones.

G. E. Harris, del. 1935.

of moisture held by the Horotiu soil at this stage is surprisingly high, for a mid-Canterbury soil of finer texture—silt loam—when wetted to its field-capacity holds only 27 per cent. of moisture. It was found that on 4th February the soils, in general, were more moist than on 10th December, and the percentages gradually increased following the normal rains of autumn and winter. On the 7th May the position was :—

Soil Type.	Percentage of Moisture.	Soil Type.	Percentage of Moisture.
Hamilton clay loam	36·1	Ohaupo silt loam	58·2
Horotiu sandy loam	52·4	Te Kowhai silt loam	53·9

The soils contain an abnormally high percentage of moisture during winter. They are probably somewhere near field-capacity—the actual field-capacity cannot be less than the above percentages.* For three of the types the field-capacity must be at least double that of the mid-Canterbury silt loams quoted above. The Kaipaki peaty soils do not behave like the non-peaty types. They were moist on the 10th December, and some time in the summer began to dry out as the water-table was lowered. The topsoil became dry and powdery, and in some fields even up to the last date of collecting—16th May—was still in this condition. The moisture in December on a Kaipaki soil was 59·3, and a comparable sample from this type on 16th May contained only 34·4 per cent. This type becomes moist when the water-table rises to the subsoil. Thus some of the Waipa soils show extraordinary features as regards moisture and are worth more attention.

From late in November to the middle of May of this field season Mr. C. F. Sutherland, of the Soil Survey, made a total of 196 point and observational analyses of the pastures on the main soil types. The bulk of these records may be regarded as fairly accurate, for the observer had a good idea of percentages from his point-analysis results. The work was undertaken to find out the difference between pastures on each soil type and to get the changing composition through the seasons. At this stage little of value can be contributed on the subject.

The following is the average composition of eighty-one pastures on all soil types, including peats. The data were collected between 13th April and 10th May and are, of course, different at other seasons of the year. The figures, however, give a general idea of the make up of Waipa pastures :—

	Per Cent.		Per Cent.
Rye-grass	38	*Lotus major*	2
White clover	14	Sweet vernal	1
Paspalum	11	Crested dogstail	1
Brown-top	7	Chewings fescue	1
Yorkshire fog	6	Weeds	9
Cocksfoot	5		

Timothy, *Poa pratensis*, tall fescue, and subterranean clover were also present, each to the extent of less than 1 per cent.

In this report most attention is given to the rye-grass and white clover, for the question of whether a pasture is grass-dominant or clover-dominant has some bearing on feed-flavour in butter.†

In the table below are the percentages of rye-grass and white clover on the main soil types between November and May. The percentages are averages of all the observations made on each type.

TABLE A.

	Hamilton.			Ohaupo.			Horotiu.			Te Kowhai.		
	29th Nov.–10th Dec.	7th Feb.–1st Mar.	13th April–10th May.	29th Nov.–10th Dec.	7th Feb.–1st Mar.	13th April–10th May.	29th Nov.–10th Dec.	7th Feb.–1st Mar.	13th April–10th May.	29th Nov.–10th Dec.	7th Feb.–1st Mar.	13th April–10th May.
Rye-grass ..	33	33	53	28	39	38	31	41	53	32	25	45
White clover ..	22	19	15	41	24	24	23	10	6	36	23	22

It will be noticed that during early December clover was dominant over rye-grass on the Ohaupo and Te Kowhai soils. It was very much the dominant constituent on the former type. In February and from April to May clovers, though not dominant in any, reach their highest percentages on the Ohaupo and Te Kowhai soils. The position, then, is that Ohaupo and Te Kowhai types are more favourable to clover-growth than the Hamilton and Horotiu types.

Two typical pastures on each type—the same field was examined at each period—were selected in order to find out the variation in rye-grass and clover percentages with the season. The table below shows that on the Ohaupo and Te Kowhai types clover passes from a dominant position in December to a subdominant place in February and April.

TABLE B.

	Hamilton Clay Loam.			Ohaupo Silt Loam.			Horotiu Sandy Loam.			Te Kowhai Loam.		
	5th Dec.	13th Feb.	18th April.	29th Nov.	9th Feb.	15th April.	4th Dec.	11th Feb.	17th April.	6th Dec.	14th Feb.	29th April.
Rye-grass ..	31	36	65	29	45	48	36	54	64	25	33	61
White clover ..	33	28	6	44	27	27	21	9	6	39	27	20

* From analysis just received it can be said that the field-capacity of Ohaupo silt loam is about 80 per cent. moisture.

† E. Bruce Levy : "Investigations of Feed-flavour in Butter." N.Z. Jour. Agri., Vol. 50, pp. 135–47 : 1935.

On the Hamilton type it goes from a slight excess over rye-grass in December to a subdominant position in February and to a very low figure in April, and on Horotiu soils it passes from a subdominant position in December to very low figures in February and April. Clover thus shows a big drop in late autumn on the Hamilton and Horotiu soils, and this is most likely explained by the fact that these two soils dry out badly during summer. This probably is the cause of the average low percentages for clover in all periods on these types of soil.

PRELIMINARY OBSERVATIONS ON THE ORCHARD SOILS OF CENTRAL OTAGO.

(By L. I. Grange.)

Introduction.

The writer accompanied Mr. F. R. Callaghan on his brief inspection of the orchards of Central Otago during March, 1935. The object of the writer's visit was to see what part investigations on the soils could play in orchard research. They received much assistance from the Orchard Instructors.

Guided by Mr. W. R. L. Williams and Mr. T. Sharp, Orchard Instructors at Alexandra, orchards at Alexandra, Earnscleugh, Clyde, Cromwell, and Lowburn, were visited and by Mr. G. H. McIndoe, Orchard Instructor at Dunedin, others at Coal Creek, Roxburgh, Dunbarton, Ettrick, and Craig Flat, south of Miller's Flat.

Climate.

Alexandra, Clyde, and Cromwell receive from 14 in. to 15 in. of rain. Southward the rainfall increases, reaching 21·56 in. at Roxburgh, and is probably several inches more at Craig Flat. These districts come in Kidson's B rainfall area; the fall is highest in December and January and lowest in June and July. Other low rainfall months are June, September, and February.

At Ophir, north-east of Alexandra, the mean temperature in January is 62·3° F. and falls to 32·1° F. in June.

Soils.

The orchard soils are derived from:—

(1) Water-sorted material forming terraces bordering the Clutha and Molyneux Rivers and some of its branches.
(2) Debris of fans built out on the Clutha and Molyneux Rivers terraces.
(3) Wind-borne and residual material on the lower slopes of the mountains.

A small amount of dust blown from the mountains has no doubt been deposited on the water-sorted material on the river-flats. The parent material of all the soils is mica schist.

The soils of the river-terraces are mainly light in texture. Where the terraces are wide the soils on the back portion of the terraces are of a heavier texture. Examples of light-textured soils are:—

(*a*) Alexandra, on the north side of the town, where the soil and subsoil extends to a depth of 2 ft., and is a sandy silt;
(*b*) Ettrick, for a distance of about a mile from the river, where the profile is 12 in. light-brown gravelly sand, resting on shingle; and
(*c*) Craig Flat, the profile being 18 in. cream-coloured silt, on sands containing layers of dark grey silt loam.

On the back slopes of the terraces at Ettrick and Earnscleugh the texture is that of a silt loam, which, in one place on the former flat, is 10 ft. or more in thickness. The amount of clay in the soil is less than that in the loess soils of Canterbury and Otago. The soil on the terraces bordering streams draining to the Molyneux River was observed in one locality—Omeo Creek, west of Alexandra, where it is a gravelly silt loam, containing less clay than the silt loam of Ettrick and Earnscleugh.

The fans lie at the mouths of small creeks or dry valleys. They are built up during thunderstorms or periods of general heavy rain. The soil texture ranges from a silt to a silt loam and stony silt loam. When big floods of short duration have taken place the soil deposited on the fan is a silt—the clay fraction has been mostly swept into the river. A recent flooding on a fan a few miles north of Clyde deposited 3 in. of cream-coloured silt. One of the fans on the west side of the river, north of Clyde, is covered with light-coloured silt to a depth of 2 ft. The soil on a fan on the south side of Roxburgh is a moderately stony silt loam containing only a small percentage of clay. On a fan to the south of the silty one, on the west bank of the river, north of Clyde, the soil, except on narrow low ridges, is a silt loam similar to that on the back slopes of the terraces at Ettrick. The depth to the shingle near the head of all the fans amounts to several feet, and on the river-banks it thins to 2 ft. to 3 ft.

The soils on the lower slopes of the mountains were seen at Ripponvale and at Lowburn. At both localities the texture of the soil and subsoil is that of a silt loam like that at Ettrick. The Lowburn subsoil is more compact than that at Ripponvale.

In general, to a depth of about 9 in., the topsoil is light grey in colour and subsoil a light yellowish-brown or creamy-yellow. Judged by their colour, they are low in humus. Still lower in humus are the silts and sandy silts, which have a creamy colour. The silt loams have a crumb structure—a structure that may be considered ideal—whereas the fractions of the light-textured soils are loose and separate. The shallowest orchard soils seen are those close to the river at Ettrick, where the depth to the shingle is 1 ft.

Investigations in Orchard Soils required.

The first essential is a map of the soil types. This would present no difficulties as the range of climate for all the orchards is small and the original vegetation and the parent material (so far as is known) in all are the same. The soils can probably be classed as one series, and divisions made according to texture. These statements need to be checked, particularly as regards parent material, for the water-sorted soils of the terraces possibly have a somewhat different composition from those of the fans and slopes. In making soil types the soil profile to a depth of 5 ft. to 6 ft. will have to be considered. Such maps will form a basis for all fruit investigations.

The plant-food status of the soil types requires to be determined. Manurial trials made by the Department of Agriculture in several of the Otago Central orchards have shown that there is a marked response to ammonium sulphate and a very slight response to phosphate, and, in some stone-fruit orchards, no visible response anywhere to potash top-dressings. Similar results have been obtained in other parts of New Zealand, except that potash has been found to be beneficial in cases of dieback. It seems that on present knowledge the phosphate status of orchard soils needs no detailed attention, or, to be on the safe side, one may say if the phosphate-content of the soil is extremely low this plant-food could not be neglected, but the phosphate-content of Otago Central soils is known to be above the average for New Zealand soils.* Available and exchangeable potash figures for the soils should be known. They may be low in the silts. But most attention should be given to the nitrogen status of the soils. As mentioned previously, the soils are thought to be low in humus. Aston's figures in the article already quoted for total nitrogen are low for New Zealand soils. The available nitrogen is a better indicator, and this needs to be determined. The fact that there is a response to nitrogenous top-dressings indicates that the store of nitrogen in the soil should be built up. One way of doing this is to grow cover-crops. Already a few of the orchardists are sowing red clover in the autumn and ploughing under in the spring of the following year. pH determinations can be made on the soil to a depth of 9 ft. to 6 ft. Chemical analyses for soluble salts are also required. In one locality north of Clyde an incrustation of soluble salts was noticed on the shingle at a depth of 3 ft.

There is room for a good deal of work on soil moisture and irrigation. Before discussing this aspect of orchard investigation it is necessary to define three terms commonly used in detailing with these subjects. Field-capacity is the amount of water that the soil can hold against the force of gravitation. The permanent wilting percentage is that at which plants wilt and do not recover. When permanent wilting is reached the leaves droop, usually during the afternoon, and do not recover the following morning. Soil-moisture between permanent wilting-point and field-capacity is readily available moisture.

Experiments by Vehmeyer and Hendrickson in orchards in California have shown that:—

(1) Fine-textured soils hold more water at field-capacity than sands.
(2) The permanent wilting percentage is best obtained by determining the moisture in the soil when wilting has taken place. Laboratory methods are not satisfactory.
(3) There is no optimum soil-moisture content. Trees obtain adequate moisture from any soil whose moisture-content lies anywhere between permanent wilting and field-capacity.
(4) Evaporation causes loss of moisture only to a depth of 8 in. or so; moisture in the soil at greater depths is lost by transpiration.
(5) If the soil is at the permanent wilting-point for only a few days no harm is done to the trees.
(6) The soil should be wetted to a depth of 5 ft. to 6 ft., for this is the location of the great bulk of the roots.
(7) Irrigation in the spring is, in general, desirable if the winter rains have been insufficient to wet the soil to a depth of 5 ft. to 6 ft.
(8) Cover-crops do not conserve moisture; owing to transpiration, more water is required when cover-crops are used.
(9) Cultivation itself does not conserve moisture. Its main effect is in destroying weeds, and thus lessening the loss by transpiration. Cultivation is done to bury cover-crops or weeds, to fill cracks resulting from drying, and to smooth the ground before harvesting.

The soil types will form a basis for work on soil-moisture. On silt and sandy types the irrigation water can run for a shorter period than on the heavier types.

It seems necessary to determine for Central Otago soils the permanent wilting percentage. If an orchardist knows the appearance of his soil before the onset of permanent wilting he can better plan his irrigation.

It is worth while finding out whether the soils to a depth of 5 ft. to 6 ft. are close to field-capacity in the spring. As the rainfall is low during the winter it is probable they are below field-capacity. Again, where cover-crops are grown there is much loss by transpiration. If the moisture-content is found to be low in the spring an irrigation can be given. Thus it may be possible to lengthen the period of the year in which irrigation is done, and thus lessen the demand for water in the summer. This is an important consideration in areas where the water comes from small creeks. If field-capacity is determined for each type of soil, then the orchardist can tell from inspection whether the soils are well stocked with water in the spring.

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* B. C. Aston: "Studies in New Zealand Soils: The Mica-schist Silts." N.Z. Jour. Agric., Vol. 26, pp. 329–33; 1923.

Investigations are needed to find out the best method of irrigation. Furrows may be placed so far apart that the intervening ground receives no irrigation water. In this connection a study of penetration profiles is helpful. Californian workers have found that a soil with a similar field-capacity to that of the silt loam of Central Otago was wetted for a distance of only 2½ ft. from the centre of the furrow.

Work on soil-moisture can be undertaken in co-operation with the pomologist.

MORTON MAINS DISEASE.

(By L. I. Grange.)

From 30th October to 9th November the writer was in southern Southland examining the soils in company with Dr. J. N. Dixon, who was engaged in the deficiency-disease investigations in that district. The main object of his investigation was to ascertain whether the soils on which anæmia in sheep occurs are different from those on which the sheep are healthy. At the same time he was acquainted by Dr. Dixon of the farm practice in healthy and unhealthy farms.

The anæmia occurs at Otara, east of the Mataura River; at Morton Mains, Edendale, Oteramika, and Longbush, between the Mataura and Orcti Rivers; at Waiponga and Gummies Flat, west of the Aparima River; and possibly at Glencoe, to the north of Morton Mains. In all these localities there are healthy farms close by the unhealthy farms. No cases of sickness are known in the Waiau Valley.

The soils of the southern part of Southland and Wallace Counties are derived from—

(1) River alluvium.
(2) Dune sands.
(3) Peat.
(4) Loess.

The river alluvium occupies wide, low flats bordering the Mataura, Oreti, Waiau, and Aparima Rivers. Blown sands are confined to a narrow belt bordering the coast, being well developed to the west and south of Invercargill. Peats occur at the back of the sandhills west of Invercargill.

The loess covers the gently rolling and hill country, the former type of topography forming by far the greater portion of the southern part of Southland and Wallace Counties. Since it is only on the gently rolling country that the anæmia occurs, the loess soils are the only types that need consideration. The loess is at its maximum 5 ft. to 6 ft. thick and covers the land fairly uniformly. In the Morton Mains district the deposit overlies conglomerate containing quartz pebbles, rotten greywacke pebbles, and occasional schist pebbles. Westward to Waipanga the number of quartz pebbles decreases. On the north side of the Titipua Stream the loess rests on quartz conglomerate, and at Glencoe, to the north of Titipua, it is above quartz conglomerate and sand and greywacke conglomerate. At Orepuke it lies on silts and shales. East of the Mataura River the loess overlies sandstone, mudstone, and conglomerate of Meszoic age. The evidence for the loessic nature of the deposit covering the rolling country is—

(1) The deposit follows the contour of the land in much the same way as do subaerial deposits of volcanic ash. Sections exposed in the alluvial workings to the west of Colac Bay show that the deposit maintains an even thickness on a moderately sloping surface. (On fairly steep slopes and on some ridge crests the deposit has been eroded away.)
(2) In the great majority of cases, where it rests on conglomerate containing quartz no quartz pebbles are found in it; this demonstrates that it is not residual.
(3) The remarkable uniformity in texture—the prevailing texture is that of a silt loam. At one locality—namely, Glencoe—the texture is that of a clay loam.
(4) The minerals in the sand fraction show a general similarity. The most abundant minerals are feldspar and quartz, and in subordinate amount are clinohypersthene and epidote.

Granting that the deposit is loess, one has then to examine whether the dust in different localities is of the same composition. The dust derived from river-beds may be of different composition. The Mataura River in its headwaters is in schist country and in its lower course in Tertiary sedimentaries and greywacke. The Oreti and Aparima Rivers drain through greywacke and Tertiary sedimentaries. The Waiau River drains igneous rocks, greywacke, and Tertiary limestone, mudstone, &c. It seems that the main differences are that the Mataura is bringing down some weathered schist and the Waiau some weathered igneous rocks. However, the main rivers to consider are the Mataura, Oreti, and Aparima, for only in these valleys are unhealthy along with healthy farms found. It is to be expected that the main difference between schist and greywacke would be that the former would build up the supply of available potash (the evidence is against potash being the cause of the diseases). An examination of the mineral constituents of the soils reveals no significant differences.

Thus from the point of view of origin, the soils may all be classed as similar. Also it may be said that chemical analyses support this statement.

Divisions in the loess can be made on the basis of the profile. On the areas where the native vegetation is or has been forest, a podsol profile is developed—

2 in. black peaty loam;
4 in. grey silt loam;
3 in. brown silt loam;
On yellowish-brown silt loam.

The grey A horizon of the podsol is well seen. There is less clay in it than in the underlayers. It has not the powdery structure of normal podsols, but has a crumb structure. The B horizon is stained with iron oxide and humus. The biggest areas of bush are east from Woodend (near Invercargill) to the Mataura River and west of Riverton. All these areas covered or recently covered with forest constitute a soil type.

On tussock land the usual profile is—

10 in. dark-brown silt loam with big crumb structure;
On yellowish-brown compact silt loam.

Iron concretions ¼ in. in diameter occur at 10 in. to 18 in. below the surface. Worm-borings extend to 22 in. below the surface. It is a podsol profile less developed than that under forest, and constitutes another soil type.

East of the Mataura River, at Otara, the profile is—

11 in. greyish silt loam with crumb structure;
6 in. brown silt loam stained and cemented with iron oxide;
On creamy-yellow silt loam.

On the arrival of the Europeans the vegetation was red tussock and flax, but, judged by the profile, forest must have flourished on it at an earlier period. This could be classed with the type now under forest.

The soil at Titipua and across to Glencoe, all originally under red tussock, is probably a separate type, for it appears to show more weathering than the profile under tussock in other parts.

The sickness is confined chiefly to the soil type under tussock, localities being Morton Mains, Edendale, Oteramika, Longbush, Waipanga, and Gummies Flat. It also occurs at Otara on the type which is like that under forest. Where the vegetation is tussock there are also many farms on which no sickness occurs. The disease is apparently not caused by the lack of a mineral which is leached from the soil, for the district west of Riverton has a higher rainfall than other parts, yet is free from trouble. Again, the Otara soils are more leached than those at Morton Mains, but the intensity of the disease in both areas seems to be about the same. The occurrence of the disease on some farms and complete freedom from the disease on others on the one soil type is against the view that any mineral deficiency or excess is the primary cause of the trouble.

A good deal of time should be spent in finding a cure—a cure may be found and the cause left uncertain. A cure or amelioration of the disease may be obtained by the use of a suitable local lick. Dr. Dixon has already sought a local lick when he tried drenching with Morton Mains subsoil, but this was found to be of no use. Dr. Dixon and the writer took a sample of weathered norite from a quarry in Henderson Street at the Bluff. The section there is—

2 ft. to 5 ft. sandy silt;
1 ft. reddish-brown sandy loam;
2 ft. yellowish-brown sandy loam;
7 ft. weathered norite.

The top 2 ft. to 5 ft. of sandy silt is discarded as it is mostly of subaerial origin. The sample was taken from the 1 ft. layer. As the fresh rock contains 4·85 per cent. Fe_2O_3 and 10·55 per cent. FeO the weathered product may reasonably be expected to be high in iron. In this respect it is similar to the limonite which has given good results as a lick in the Rotorua district. The lick is worth a trial.

ANNUAL REPORT OF THE CHEMICAL WORK AT THE CAWTHRON INSTITUTE FOR 1934–35.

(By T. Rigg.)

During the past year the conduct of mechanical and chemical analyses of Ashburton soils has been the most important feature of the soil-survey work undertaken at the Cawthron Institute. In addition, further work has been done on the potash status of Taranaki soils enabling a very definite correlation to be made between the chemical data and the actual field responses with potassic manures obtained by the Department of Agriculture.

In conjunction with the field-workers, a survey of the moisture status of typical Waipa soils has been made at regular intervals during the summer and autumn.

Ashburton Soils.

The mechanical and chemical analyses of soil samples collected by Dr. L. I. Grange in connection with the soil survey of Ashburton County have been completed. The mechanical analyses show that the loess covering of the plains belongs to the silt-textural group. The percentage of silt, over a wide range of samples, shows little departure from an average figure of 28 per cent. The clay fraction in typical loess soils of the plains varies only from 18 per cent. to 20 per cent. The depth of the loess soil and the presence of gravels either in the surface soil or in the underlying layers frequently greatly influences not only the textural properties of the loess soils, but also their moisture status.

In the case of soils associated with the Rakaia, Ashburton, Rangitata, and Hinds Rivers systems, more variation in texture is experienced, and clay loams are almost as frequent as silt loams in the textural types which have been identified by Dr. Grange. For these soils associated with the rivers of the Ashburton County the percentage of silt varies from 27 per cent. to 41 per cent. and that of clay varies from 17 per cent. to 30 per cent.

The chemical examination of Ashburton soils by Miss E. B. Kidson has brought out several points of considerable interest. The percentages of available phosphoric acid as determined by the 1-per-cent. citric-acid method show striking differences in different parts of the county. A careful study has been made to ascertain the distribution of soils associated with high phosphate-content in contradistinction to soils showing comparatively low phosphate figures. The examinations have shown that high figures for phosphoric acid are restricted to particular areas in the vicinity of the main-river systems and are

not associated with the old loess soil of the plains. The analyses have shown that the old loess soils rarely exceed 0·015 per cent. phosphoric acid, and in certain cases the percentage is as low as 0·008 per cent. In the case of soils of recent formation associated with the river systems those of the Rakaia, Ashburton, and Rangitata Rivers were found to be of high phosphate availability, giving percentages ranging from 0·035 to 0·018 per cent. Alluvial soils of the Hinds River, which has a local origin, showed, on the other hand, a low available phosphate-content, resembling in this respect the old loess soils.

Samples of river sediment supplied by Mr. Beck, of the Public Works Department, who suspected that the river sediments contributed to the fertility of the plains, were found to contain a relatively large amount of available phosphoric acid, suggesting that the soils of the river-systems are greatly influenced by the deposition of sediments brought down from the mountains in time of flood.

The fact that no soils rich in available phosphate are associated with the Hinds River system may be accounted for by the more local origin of this river and the fact that much of the silt brought down in times of flood is derived from ancient deposits now forming foothills and probably belonging to the same period as the old loess soils of the plains.

Extraction of Ashburton soils with strong hydrochloric acid shows that the amount of phosphate extracted by this reagent is not unusually large, and in this respect Ashburton soils compare unfavourably with Taranaki soils, which are noted for the high figures obtained for phosphoric acid under the hydrochloric-acid extraction. Ashburton soils of high phosphate availability do, however, give somewhat larger amounts of hydrochloric-acid soluble phosphate than those of low phosphate availability.

The analytical data obtained by Miss Kidson suggest that the parent material from which Ashburton soils have been derived has remained fairly constant in phosphate status over a very long period covering the formation of the Canterbury Plains. The differences in phosphate availability, so marked at the present time, are probably connected with the weathering and leaching of the old loess soils in contrast to an unweathered condition of the fine rock particles forming the recent loess and alluvial soils.

Somewhat high soil acidity, particularly in the case of samples taken from the old loess area in the county, supports this contention. Average figures for pH values of Ashburton soils show a figure of 5·54 in the case of soils formed in recent times and a value of 5·36 for soils of the old loess type.

With few exceptions the available potash figures for Ashburton soils are satisfactory, indicating that potassic manures under present farming conditions are not likely to be required.

Taranaki Soils.

In a previous report mention has been made of the great variation in available potash figures found in soils collected in different parts of Taranaki. Very high figures were found in the case of soil samples collected in the Patea locality, while very low figures were associated with soils taken from the Stratford-Inglewood district. The results did not show any close correlation with the volcanic showers mapped by Grange and Taylor, but appeared to be connected with rainfall conditions prevailing in different districts.

An opportunity was taken during the past season of securing additional samples from fields and areas where the Fields Division of the Department of Agriculture had established manurial-responses plots. The analytical data from these soil samples have enabled a much clearer picture to be obtained concerning the potash status of Taranaki soils.

Table I.—Taranaki Soils (Northern Sector).

Available Potash soluble in 1-per-Cent. Citric Acid.

Laboratory No.	Depth of Sampling.	Soil Series.	Locality.	Available Potash.	Remarks.
	In.			Per Cent.	
433 ..	0–3	Stratford sand	Toko ..	0·017	G. Were (owner).
441 ..	0–3	,, ...	Stratford ..	0·018	Stratford Demonstration Farm.
945 ..	0–3	,, ...	Waipuku ..	0·016	W. Hooker (owner).
949 ..	0–3	,, ...	Huirangi ..	0·010	W. Hall (owner).
447 ..	0–3	,, ...	Kaimata ..	0·016	J. Klenner (owner).
445 ..	0·3	Stratford sandy loam ..	Tikorangi ..	0·016	J. H. Paulger (owner).
483 ..	0–3	Stratford sand	Inglewood ..	0·016	Four miles north of Inglewood.
485 ..	0–3	Stratford sandy loam ..	Lepperton ..	0·019	One mile south of Lepperton Station.
497 ..	0–3	Inglewood coarse sandy loam	Inglewood ..	0·012	W. Lawrence. No treatment for thirteen years.
499 ..	0–3	Hangatahua loam ..	,, ..	0·024	Dudley Road.
501 ..	0–3	Patua loam	,, ..	0·012	Durham Road.
503 ..	0–3	Inglewood coarse sandy loam	,, ..	0·011	,,
505 ..	0–3	Norfolk sand	Tariki ..	0·025	Bedford Road.
947 ..	0–3	Inglewood coarse sandy loam	Inglewood ..	0·012	Sample from Marsh's property.
953 ..	0–3	Patua loam	Mangaorei Road	0·011	Sample from Pearce's property.
509 ..	0–3	,, ...	Patua ..	0·018	..
951 ..	0–3	Egmont black loam ..	Lepperton ..	0·012	Sample from Sole's property.
487 ..	0–3	,, ..	,, ..	0·012	Bell Block.
489 ..	0–3	Egmont brown loam ..	New Plymouth	0·010	Smart Road.
507 ..	0–3	Egmont black loam ..	Onairo ..	0·027	Elliot's property near sea-coast.
491 ..	0–3	Egmont brown loam ..	New Plymouth	0·022	Barrets Road.
493 ..	0–3	Egmont black loam ..	,,	0·032	Koru Road near sea-coast.
495 ..	0–3	Warea loam	Warea ..	0·018	Sample from Ruakere Road.
525 ..	0–3	Hangatahua sand	Okato ..	0·019	Water-sorted sands from Gray's property.

TABLE II.—TARANAKI SOILS (SOUTH-EAST SECTOR).

Available Potash soluble in 1-per-Cent. Citric Acid.

Laboratory No.	Depth of Sampling.	Soil Series.	Locality.	Available Potash.	Remarks.
	In.			Per Cent.	
437 ..	0–2	Egmont brown loam ..	Hawera ..	0·025	From Parker's property.
467 ..	0–3	Eltham peaty loam ..	Eltham ..	0·036	From Belcher's property.
935 ..	0–3	Egmont brown loam ..	Normanby ..	0·019	From A. Newall's property.
473 ..	0–3	,, ..	,, ..	0·033	,,
475 ..	0–3	,, ..	Hawera ..	0·022	From McKenzie's property.
477 ..	0–3	Egmont black loam ..	Patea ..	0·059	From Welsh's property.
481 ..	0–3	,, ..	Alton ..	0·042	From Hodge's property.

TABLE III.—TARANAKI SOILS (SOUTH-WEST SECTOR).

Laboratory No.	Depth of Sampling.	Soil Series.	Locality.	Available Potash.	Remarks.
	In.			Per Cent.	
943 ..	0–3	Glenn loam	Manaia ..	0·020	Gamlin's property.
443 ..	0–3	Egmont black loam ..	,, ..	0·033	State farm.
479 ..	0–3	,, ..	Okaiawa ..	0·034	John's property.
939 ..	0–3	,, ..	Manaia ..	0·028	Espiner's property.
941 ..	0–3	,, ..	Otakeho ..	0·014	Will's property.
453 ..	0–3	,, ..	Pihama ..	0·022	Pettigrew's property.
937 ..	0–3	Egmont brown loam ..	Normanby ..	0·019	Frank's property.
463 ..	0–3	Stratford sandy loam ..	Mangatoki ..	0·023	Parker's property.
449 ..	0–3	Warea loam	Oaonui ..	0·032	Pennington's property.

The figures for available potash in connection with Taranaki soils are shown in Tables I–III. For convenience in discussing the results the soil samples have been grouped for three areas of Taranaki where somewhat different conditions in regard to potash status prevail. In Table I soil samples for the sector north of a line drawn between Cape Egmont and Stratford are tabulated. In this sector many of the soil samples, particularly in the Stratford, Inglewood, and Lepperton areas, are outstandingly low in available potash. In only five soils out of twenty-four samples do the figures for available potash in the top 3 in. exceed 0·020 per cent., and in a number of instances the figures for potash fall to the low level of 0·010 per cent.

In the above sector the soil types which appear to be uniformly low in available potash are the Inglewood coarse sandy loam, the Stratford sand and sandy loams, and the Patua loam. In the case of the Egmont black and brown loams the figures are also low with two or three outstanding exceptions. The samples from Onairo and Koru Road, both taken on the Egmont black loam soil type, came from locations in close proximity to the sea, and in these cases the influence of salt spray from the sea has improved in all probability the potash status of the soils. Figures for the isolated soil samples taken from the Hangatahua loam and the Norfolk sand types are above the average in potash-supply, but the number of samples in these cases is not sufficient to allow any generalization to be made in connection with the potash status of these two soil types.

It would appear that the whole area north of Stratford and Cape Egmont is generally low in potash and that with few exceptions a definite response should be obtained with potassic manures on pastures.

In Table II soil samples for the south-east sector of Taranaki are tabulated. This sector covers that part of Taranaki south-east of a line drawn through Stratford, Eltham, and Hawera. In this sector the figures for available potash in the top 3 in. of soil are high, and in certain cases, notably in the direction of Patea, the percentages of potash in the soils are outstanding in this respect.

While it is probably safe to assume that potassic manures will not show any response in the case of pastures located in the Alton and Patea locality, the position in the Normanby and Hawera locality is not so definite, and certain farms and fields may well show some benefit from potassic manures. Generally speaking, however, this south-east sector of Taranaki is the one where the least effect from potassic manures may be expected. In Table III soil samples from the south-west sector of Taranaki are presented. Six samples of the nine shown in the table came from the Egmont loam soil types. In many cases the analytical data suggest a satisfactory potash status, but very noticeable exceptions occur in the samples from Normanby and Otakeho. The figures for Will's property, 0·014 per cent. available potash, is as low as those found in the northern sector of Taranaki discussed under Table I. The occurrence of wide divergencies of this nature in potash-supply is difficult to understand and suggests that other farms or fields on particular farms in this sector will also have a low potash status.

Under these circumstances no generalization concerning the use of potassic manures can be made for this area of Taranaki. Field-plot tests and a much wider sampling of soils for laboratory examination will be necessary in order to clarify the position in regard to the use of potassic manures by the farmer.

One interesting feature of the laboratory examinations of Taranaki soils is the good correlation which has been obtained between the actual field response to potassic manures and the potash status of the soil.

Through the kindness of the Director of the Fields Division and the Crop Experimentalist of the Department of Agriculture information is available concerning the actual field response with potassic manures in the case of a number of pastures from which soil samples have been obtained. In the following Table IV some of the chemical results are shown for a number of pasture soils where the effect of potassic manures has been determined.

TABLE IV.—TARANAKI SOILS.

Chemical Analyses and Field Response to Potassic Manures.

Laboratory No.	Depth of Sampling.	Available P_2O_5.	Plant Food, K_2O.	pH Value in Water.	Lime-requirement Figure.	Response to Potash.	Remarks.
	In.						
935	0–3	0·043	0·019	5·84	0·30	Nil ..	Newell's property.
937	0–3	0·049	0·019	5·74	0·29	Good ..	Frank's property.
939	0–3	0·038	0·028	5·79	0·45	Nil ..	Espiner's property.
941	0–3	0·037	0·014	6·01	0·33	Good ..	Will's property.
943	0–3	0·036	0·020	5·88	0·23	Fair ..	Gamlin's property.
945	0–3	0·056	0·016	5·84	0·42	Good ..	Hooker's property.
947	0–3	0·057	0·012	5·79	0·59	„ ..	Marsh's property.
949	0–3	0·035	0·010	5·96	0·49	„ ..	Hall's property.
953	0–3	0·056	0·011	5·70	0·55	Very good	Pearce's property.

With one exception, soils containing less than 0·020 per cent. potash in the top 3 in. of soil have given fair to very good responses with potassic manures. In the case of sample 939, from Espiner's property, no response was noted in the field trials of the Department of Agriculture, in agreement with the higher potash status (0·028 per cent. available potash) of this soil.

Samples Nos. 935 and 937 provide a discrepancy in the correlation of the analytical data with the field results. In these two samples the percentage of available potash is 0·019 per cent., and in one case a good response has been reported and in the other no response. As the soil samples were collected from adjoining land outside the experimental area there is a possibility even in this case of abnormal soil conditions operating on one farm which might explain the divergence noted in the field response to potassic manures. Further field observations and laboratory examinations are desirable to clear up this anomaly.

In the conduct of the work covered by this report Miss E. B. Kidson, M.Sc., has been responsible for the chemical determinations and Mr. L. Hodgson for the mechanical analyses.

SOILS OF ASHBURTON COUNTY IN RELATION TO IRRIGATION.

(By L. I. GRANGE.)

INTRODUCTION.

A soil survey of the plains of Ashburton County was made in 1933 and the mechanical and chemical analyses completed at the Cawthron Institute a short time ago. For assistance in the field the Department is indebted to the Ashburton County Council and to the Unemployment Board, both of which paid a part of the wages of field hands. The Council also assisted in many other ways. Mr. T. Rigg and Miss E. B. Kidson, of the Cawthron Institute, are submitting a report on the samples which they have analysed. Mr. J. Fleming, of Methven, is preparing, under Dr. I. W. Weston's direction, an account of farm-management based on the soil map and aided by a valuation map which the writer had prepared while in Ashburton.

CLIMATE.

The average rainfall* for stations on the plains of Ashburton County is :—

TABLE I.—ANNUAL RAINFALL.

Station.	Inches.
Evandale, Mount Somers	33
Mount Somers	38
Rudstone, Methven (Jas. Carr)	38
Methven Post-office	38
Drayton, Methven†	41
Bicton, Methven†	45
Staveley	43
Singletree, Alford Forest	46
Fairview, Springburn	33
Mayfield†	36
Rakaia (Miss Hardy)	28
Winchmore (C. H. Jones)	29
Ashburton	28
Lyndford, Hinds	26
Ealing†	29

* All rainfall data have been obtained from Dr. E. Kidson, Director of Meteorological Services, Wellington.

† These stations are not now reporting.

H. 34

SOIL MAP OF PART OF
ASHBURTON COUNTY
CANTERBURY

SCALE

CHAINS 40 20 0 5 MILES

K.M. 0 5 10 15 K.M.

1 126720

J. HENDERSON
DIRECTOR

TOPOGRAPHY.	LANDS & SURVEY DEPT.
FARMERS' NAMES.	ASHBURTON ELECTRIC POWER BOARD.
SOIL TYPES.	J. T. GRANGE, S.I.R.D.S.I.

LEGEND

WEAKLY PODSOLIZED SOILS (A)

- Mt Somers silt loam
- 2 Andrews silt loam

WEAKLY PODSOLIZED SOILS (B)

- 3 Staveley stony silt loam
- 3a Do (Wet phase)
- 4 Springburn silt loam
- 5 Ruapuna stony silt loam
- 6 Rangitata bouldery silt loam
- 7 Breckenridge stony silt loam and stony loam
- 8 Gorge silt loam

WEAKLY PODSOLIZED SOILS (C)

- Carrubrae stony silt loam
- 12 Seafield silt loam
- 12a Do (Stony phase (?))
- 12b Do (Stony phase (?))
- 13 Lismore stony silt loam
- 14 Valetta stony silt loam
- 15 Maronan stony silt loam
- 16 Chertsey silt loam

SKELETAL SOILS (A)

- 9 Methven silt loam
- 17 Wilson silt loam
- 18 Highbank silt loam
- 19 Heavy fine sands and sandy loam

SKELETAL SOILS (B)

- 20 Springfield clay loam and heavy silt loam
- 21 Mayfield silt loam and sandy loam
- 22 Harrison silt loam
- 23 Bowyer sand
- 24 North sand

SKELETAL SOILS (C)

- 10 Lyndhurst stony silt loam
- 25 Barrhill silt loam
- 26 Hatfield silt loam
- 27 Nukuta silt loam
- 28 Ealing silt loam

SKELETAL SOILS (D)

- 29 Wakanui clay loam
- 30 Riverside silt loam
- 31 Coldstream silt loam
- 32 Westerfield silt loam
- 33 Elmwald stony silt loam and silt loam
- 34 Greenstreet sandy loam and silt loam
- 35 Ringsbury stony silt and silt loam
- 36 Hinds sands
- 37 Ashburton sands

MEADOW SOILS

- 38 Rowcliffe silt loam and sandy loam
- 39 Effelton clay loam
- 40 Blackbridge silt loam
- 41 Waterton silt loam
- 42 Flemington silt loam containing iron concretions
- 43 Anderson silt loam

PEAT SOILS

- 44 Peaty silt loam
- 45 Peaty clay loam
- 46 Peat

Probably at Coldstream the rainfall is less than that of any of the above stations, for an old station, Kapunatiki, about five miles to the south of the mouth of the Rangitata, had an average of only 23 in.

From a glance at the table it is seen that the area may be roughly divided into two rainfall belts—one towards the hills from Ruapuna, Mayfield, and Cairnbrae, where the rainfall averages about 39 in., and the other towards the coast from these places, where the rainfall averages about 28 in. The Ealing average is not reliable, as the number of years is small and the record broken. If the Hinds figure of 26 in. can be taken as more indicative of the average it can be said that the lower part of the plain from the Hinds River to the Rangitata has a lower rainfall than does the Ashburton and Rakaia districts.

In the area averaging 28 in. temperatures and consequently evaporation is higher than in the moderate rainfall area.

From the point of view of irrigation the low rainfall area is important. The average monthly rainfall figures at Ashburton and Rakaia are :—

Table II.—Average Monthly Rainfall.

	Ashburton (Twenty-five to Twenty-six Years). In.	Rakaia (Thirty-one to Thirty-two Years). In.
January	2·76	2·79
February	2·12	1·95
March	1·72	2·02
April	2·26	2·13
May	2·39	2·38
June	2·36	2·74
July	2·58	2·52
August	2·09	2·25
September	2·45	2·46
October	2·33	2·22
November	2·33	1·81
December	2·71	2·70
Year	28·10	27·97

The months receiving the highest rainfall at Ashburton are January and December; at Rakaia the greatest amount of rain falls in January December, and June. Months of low rainfall at Ashburton are March, August, and February, and at Rakaia November, February, and March. Thus at the time temperatures are high, on the average, a good rainfall may be expected in December and January and a low rainfall in March and February and, in the case of Rakaia, in November.

Average monthly figures do not by any means give the true position as regards moisture. One might wonder when there is a rainfall of 2·76 in January and 2·71 in December why irrigation is talked about. A better picture is obtained by viewing the rainfall figures month by month.

Table III.—Monthly Rainfall: Ashburton (in Inches).

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
1914 ..	2·17	4·67	2·95	3·15	3·46	1·02	0·29	0·55	1·00	1·24	2·59	2·10	25·19
1915 ..	1·73	1·03	1·16	0·75	1·61	1·83	0·94	0·67	0·17	1·37	1·46	2·32	15·04
1916 ..	1·51	3·06	1·39	2·51	3·77	2·41	3·37	2·35	1·05	1·95	1·02	0·19	24·58
1917 ..	2·19	1·30	2·55	3·07	5·14	0·97	3·66	1·42	6·24	1·57	0·95	4·89	33·95
1918 ..	2·78	2·40	2·99	0·92	0·76	2·52	3·66	2·57	2·16	1·51	3·48	1·30	27·05
1919 ..	5·31	0·64	0·68	2·23	0·48	2·07	3·03	2·57	3·85	1·41	3·04	1·64	26·95
1920 ..	2·60	3·51	2·51	3·13	0·89	2·11	1·67	3·67	7·16	1·28	1·84	1·77	32·14
1921 ..	3·09	2·59	1·20	2·66	1·01	2·64	0·75	1·70	5·93	5·24	0·75	1·63	29·19
1922 ..	2·40	1·93	4·28	0·54	1·37	1·81	1·28	0·61	1·78	0·16	3·13	2·70	21·99
1923 ..	4·20	3·62	1·53	2·35	9·05	0·59	2·29	0·96	1·49	1·49	0·98	2·20	30·75
1924 ..	2·10	0·37	1·82	2·80	2·26	1·85	0·61	0·80	1·26	2·79	2·72	4·52	23·90
1925 ..	1·70	0·67	1·21	6·70	2·76	3·95	4·23	7·17	3·82	2·06	2·63	1·53	38·43
1926 ..	2·03	4·08	1·19	1·32	4·28	0·82	2·64	0·99	0·89	4·16	2·91	3·64	28·95
1927 ..	1·47	1·49	1·62	1·05	0·70	3·54	2·36	2·33	2·40	3·17	3·32	2·98	26·43
1928 ..	1·00	1·75	1·79	2·48	2·58	3·97	0·45	3·38	1·02	4·01	2·22	6·79	31·44
1929 ..	2·92	0·13	2·47	2·20	1·11	5·47	5·66	3·24	2·30	0·38	2·05	3·64	31·57
1930 ..	5·37	0·98	1·06	1·77	1·81	0·67	1·46	4·94	4·00	1·94	2·61	1·57	28·18
1931 ..	1·36	3·88	0·97	1·41	1·28	1·95	1·63	1·24	2·80	1·46	1·20	1·32	20·50
1932 ..	1·00	2·44	0·51	3·94	2·62	1·35	0·95	1·62	1·06	3·83	2·94	2·42	24·68
1933 ..	3·10	0·28	0·25	0·85	1·97	1·04	2·83	1·34	0·99	2·69	4·39	3·32	23·05
1934 ..	7·15	2·37	2·28	1·47	4·76	2·64	1·32	3·28	3·03	2·19	1·43	0·58	32·50

It is seen that at Ashburton in the period from 1914 to 1934 there were several years with low rainfall; during thirteen years of this period it was below the average in January, and during the critical period—November to March—there was at least one month of ten of the years in which the fall was less than 1 in. Then, again, the actual rain which falls in the critical months is not as useful

as it is in most other districts in New Zealand as there is a high evaporation when north-westers are blowing. The minimum amount of rain required to maintain the growth of pastures in the critical period is not known. It would depend on the type of soil—depth to the gravel and texture and, in the case of deep soils, on the amount of storage in the subsoil during winter and spring.

Parent Material.

The parent material of all the soils is fine-grained detritus of greywacke rocks. Tertiary rocks and rhyolites are thought to contribute a negligible amount to the soils. The fine-grained beds, which give rise to the soil and subsoil, rest on thick beds of closely packed greywacke gravel with a sand matrix. The surface-deposits are loess and water-sorted deposits. Loess, which is a wind-borne deposit—blown from dry river-channels and from the mountain-tops—covers a much greater area than the alluvium. The latter, coloured yellow on the map, border chiefly the Ashburton and Hinds Rivers and are spread over the low-lying coastal land between the Ashburton and Hinds Rivers.

Vegetation.

All the plain, with the exception of about ten square miles at Staveley and Alford, were originally covered with tussocks, &c. In the Staveley and Alford districts there was forest.

Soils.

Climate, parent material, and vegetation all have their effect on the soil. These factors have all gone to form the soil and subsoil characteristics, which can be observed when a vertical face of the soil to a depth of 2 ft. to 3 ft. is exposed. Ashburton soils show so many points of similarity that a classification is by no means easy. The classification adopted may not be genetically sound, but it is though to be suitable for a basis of irrigation studies. In some cases it has been found difficult to decide whether a particular soil should be a separate type or a phase of another type. The writer does not regard his soil-work as final; in areas which it is proposed to irrigate further work can be done on the soils by Mr. T. G. Beck's staff.

The soil groups recognized are:—

Weakly podsolized soils (*a*).
Weakly podsolized soils (*b*).
Weakly podsolized soils (*c*).
Skeletal soils (*a*).
Skeletal soils (*b*).
Skeletal soils (*c*).
Skeletal soils (*d*).
Peat soils.

The peat soils containing much organic matter are relatively unimportant—their total area is less than seven thousand acres—thus the main division of the soils is into weakly podsolized and skeletal soils. A podsol is a soil which has suffered a good deal of leaching. It develops in areas where the rainfall is sufficient to carry down into the subsoil certain of the products of weathering. Such soils are low in plant-foods. In the Ashburton soils the podsol process has not proceeded far and the soils are referred to as weakly podsolized. All the soils of these groups are derived from loess. The evidence for concluding that the podsol process is operating on those soils need not be stated in this report. One may think that with a rainfall of 28 in. no leaching is taking place, but from the monthly rainfall figures it is seen that a monthly fall of between 5 in. and 9 in. is not a rare occurrence. These amounts of rain are sufficient to carry soluble constituents into the subsoil.

Skeletal soils are those which are so young that they have weathered very little in their present position and have suffered very little leaching. These are the young loess and alluvial deposits.

Divisions within the group are made mainly on the thickness of the deposit on top of the gravel and on texture. Table IV sets out all the types recognized, together with the acreage of each type.

TABLE IV.—CLASSIFICATION OF ASHBURTON SOILS.

Weakly Podsolized Soils.

		Acres.
Weakly podsolized soils (*a*)—		
(1) Mount Somers silt loam	Over	3,500
(2) Andrews silt loam	Over	1,800
	Over	5,300
Weakly podsolized soils (*b*)—		
(3) Staveley stony loam	Over	2,700
(3A) Staveley stony loam, wet phase		1,300
(4) Springburn silt loam	Over	17,000
(5) Ruapuna stony silt loam		33,000
(6) Rangitata bouldery silt loam		3,000
(7) Buccleugh stony silt loam and stony loam	Over	47,200
(8) Gorge silt loam		5,700
	Over	109,900

Weakly podsolized soils (*c*)—		Acres.
(11)	Cairnbrae stony silt loam	10,100
(12)	Seafield silt loam	67,200
(12A)	Seafield silt loam, stony phase No. 1	28,000
(12B)	Seafield silt loam, stony phase No. 2	35,800
(13)	Lismore stony silt loam	68,400
(14)	Valetta stony silt loam	10,600
(15)	Maronan stony silt loam	55,100
(16)	Chertsey silt loam	35,300
		315,500

Skeletal Soils.

Skeletal soils (*a*)—			
(9)	Methven silt loam		7,500
(17)	Wilson silt loam	Over	7,500
(18)	Highbank silt loam		5,900
(19)	Carr pine sands and sandy loam		2,700
		Over	23,600
Skeletal soils (*b*)—			
(20)	Springfield clay loam and heavy silt loam		23,400
(21)	Mayfield silt loam and sandy loam	Over	14,800
(22)	Harrison silt loam	Over	2,900
(23)	Bowyer sand		3,200
(24)	North sand	Over	6,400
		Over	50,700
Skeletal soils (*c*)—			
(10)	Lyndhurst stony silt loam		35,200
(25)	Barrhill silt loam		14,200
(26)	Hatfield silt loam		15,400
(27)	Rakaia silt loam		15,500
(28)	Ealing silt loam		11,500
			91,800
Skeletal soils (*d*)—			
(29)	Wakanui clay loam		31,000
(30)	Riverside silt loam		2,300
(31)	Coldstream silt loam		3,900
(32)	Westerfield silt loam		6,900
(33)	Tinwald stony silt loam and silt loam		11,700
(34)	Greenstreet sandy loam and silt loam		22,500
(35)	Kingsbury stony silt and silt loam		4,800
(36)	Hinds sands		16,300
(37)	Ashburton sands		9,300
			108,700

Meadow Soils.

(38)	Lowcliffe silt loam and sandy loam	4,700
(39)	Eiffelton clay loam	5,400
(40)	Blackbridge silt loam	1,600
(41)	Waterton silt loam	13,700
(42)	Flemington silt loam containing iron concretions	1,500
(43)	Anderson silt loam	1,000
		27,900

Peat Soils.

(44)	Peaty silt loam	600
(45)	Peaty clay loam	5,200
(46)	Peat	1,000
		6,800

Weakly Podsolized Soils.

Three subdivisions are made—the weakly podsolized soils (*a*), derived from the oldest loess deposits lying well above the plain level; the weakly podsolized soils (*b*), of the old loess deposits of the moderate-rainfall area; and the weakly podsolized soils (*c*), of the old loess deposits of the low-rainfall belt. The soils of the subdivisions (*a*) and (*b*) are the most leached but are not as infertile as those of subdivision (*c*), which have had the topsoil removed by blowing in prehistoric times.

WEAKLY PODSOLIZED SOILS (*a*).

(1) *Mount Somers Silt Loam.**—The Mount Somers silt loam occurs on terraces lying about 150 ft. above the plain to the west of Mount Somers Railway-station. No doubt the soils on the Surrey Hills belong to this type. The loess, more than 12 ft. in thickness, is of the same age as the loess of the rolling country at the back of Timaru. The vegetation was tussock. A profile is :—

9 in. dark-grey moist crumbly silt loam ;
4 in. mottled dark-grey and creamy-yellow silt loam ;
On creamy, moist, yellow silt loam.

Iron-oxide concretions are abundant at 10 in. to 20 in. below the surface. From the feel of the subsoil one would say it is a heavy silt loam, but this may be due to the high content of moisture.

(2) *Andrews Silt Loam.*—The Andrews silt loam also lies on the high-level terraces. It differs from the Mount Somers profile in that the topsoil is light brown in colour, this being accounted for by the fact that the original vegetation was forest.

Notes on Texture and Carrying-capacity of Weakly Podsolized Soils (a).

The mechanical analyses† of the Mount Somers soil is a guide to what fractions a true loess soil should contain. The coarse-sand fraction is 2·9 per cent. in the topsoil and 3·0 per cent. in the subsoil. As some so-called loess soils of types on the plain contain much more coarse sand—up to 16 per cent. It may be reasonably doubted whether they are true loess soils—they may be admixed with the sand of the river-gravels on which the wind-borne material fell, or even, in some cases, may be mainly water-sorted beds.

The carrying-capacity of the Andrews silt loam is reckoned at 1¼ ewes per acre.

WEAKLY PODSOLIZED SOILS (*b*).

(3) *Staveley Stony Silt Loam.*—The moist soil and subsoil has a total depth of 16 in. to 18 in. and is in most places stony. The wet phase is badly drained and in parts supports a growth of rushes.

(4) *Springburn Silt Loam.*—This soil type has a total depth varying from 18 in. to 30 in. It is fairly free from stones. Like the Staveley soil, it lies at the foot of the Southern Alps and experiences a fairly high rainfall and low temperatures.

(5) *Ruapuna Stony Silt Loam.*—The total depth of this soil type is between 16 in. and 18 in. There are many stones and small boulders in it—more than in any of the other types of this group. As is well known, the stones and boulders have to be gathered into heaps to allow of cultivation of the soil.

(6) *Rangitata Bouldery Silt Loam.*—This soil type occurs on a terrace of the Rangitata River, some seven miles long and about three-quarters of a mile wide. The total depth to the gravel is from 18 in. to 20 in. The boulders occur in narrow low ridges.

(7) *Buccleugh Stony Silt Loam and Loam.*—On this type the total depth ranges from 15 in. to 19 in. The shallowest soils, 15 in., lie in the triangular area between Mayfield and Anama Railway-station. In the other areas the depths are about 19 in. Stones make up a high percentage of the soil north-west of Mayfield and are scarce to the south-east of Mount Somers Railway-station. It is quite likely that the strip between Springfield and the north branch of the Ashburton River should be classed with the skeletal soils.

(8) *Gorge Silt Loam.*—The gorge silt loam is 3 ft. and more in thickness. Most of the area which it covers lies badly, falling to the north-west.

Notes on Texture and Carrying-capacity of Weakly Podsolized Soils (b).

The Staveley, Ruapuna, Springburn, and Buccleugh types, according to analyses which have been made, do not differ greatly in their mechanical composition. All are silt loams with the exception of the soil on the south-east side of the north branch of the Ashburton River, which is a loam. Judged by the feel, the other types closely resemble these in texture. The bulk of the analysed soils contain a high percentage of the coarse sand fraction compared with the average silt loam of Ashburton Plain.

The sheep-carrying capacity of this group ranges from about 1 ewe to 1½ ewes per acre. About 1 ewe is carried on the Springburn type, 1½ on the Ruapuna type, from slightly above 1 ewe to 1½ ewes on the Buccleugh type. The Buccleugh type is not uniform in its carrying-capacity ; the area between Mayfield and Anama Railway-station carries only a little more than 1 ewe, the area between Anama Railway-station and the north branch of the Ashburton River 1¼ ewes, and that on the south-east side of the Ashburton River 1½ ewes.

WEAKLY PODSOLIZED SOILS (*c*).

These soils cover much the greater part of the wide plains between the rivers in the low-rainfall area. They are, in general, shallow soils, and this the writer considers can only be due to the removal in prehistoric days of much of the topsoil by blowing.

(11) *Cairnbrae Stony Silt Loam.*—The depth of soil and subsoil ranges from 17 in. to 22 in. Stones are most abundant at the northern end of the strip, the percentage there being above that in Lyndhurst soils. The subsoil is heavier in texture than that of the average silt loam. According to farming results, the triangular area on which are Messrs. Morris, Dwyer, and Boag's farms is a different soil

* See Appendix, A for description of soil textures.
† Mechanical analyses were made by Mr. L. Hodgson, Cawthron Institute.

type to the other part of the Cairnbrae type. No difference can be seen in the soils, except a slightly greater total depth of soil on the gravel. Probably the difference is due to a better plant-food status, and this part may be a phase of the Cairnbrae type. It must be said also that there is a better fertility in the southern end of the Cairnbrae strip than in the northern end.

(12) *Seafield Silt Loam.*—This type, extending from the coast to Seafield and to Fairton and Dromore, averages 10 in. in depth. Narrow strips occur where the depth is up to 18 in., but these make up a relatively small area. On the whole, the percentage of stones is small, though in places, as near the main road at Fairton, the soil can be classed as a stony silt loam.

(12A) *Seafield Silt Loam, Stony Phase (1).*—This phase occurs in the Lowcliffe-Hinds district and is similar to that in the Seafield district except that the soil is stony. As noted later, there is also a slight difference in texture.

(12B) *Seafield Silt Loam, Stony Phase (2).*—This phase, stretching from Lauriston to near Ashburton, is like that at Lowcliffe, differing only in the total depth, which is 11 in.

(13) *Lismore Stony Silt Loam.*—The soil and subsoil of the Lismore stony silt loam gradually increases in depth from Ealing and Hinds, 9 in., to near Ruapuna, 18 in. The boundary between the Seafield stony silt loam and the Lismore stony silt loam is not easy to determine. There is a gradation between them, so the boundary must be regarded as arbitrary. Mr. J. Fleming, on farm-management evidence, would shift the boundary to a few miles north-west of the railway-line. The Department of Agriculture report that there are occasional cases of Waihi disease in cattle grazing within the Hinds district; the Lismore soil is apparently deficient in phosphate.

(14) *Valetta Stony Silt Loam.*—This soil has a total depth of 10 in. to 11 in. It resembles somewhat the Seafield stony silt loam in the Lauriston district except that the subsoil of the former is usually the more moist. The type is doubtfully included in this group; it may belong to the weakly podsolized (*b*) group.

(15) *Maronan Stony Silt Loam.*—This is the shallowest of the main soil types. Its total depth is only 9 in. It is the most stony soil in the low-rainfall area. Its humus-content appears to be low. The boundary between it and the Valetta type is arbitrary. The soil in periods of low rainfall dries to a powder with a silty feel.

(16) *Chertsey Silt Loam.*—The Chertsey silt loam has a total depth of 18 in. An alternative to the establishment of the Chertsey type is its inclusion as a phase in the Seafield type. Farmers state that the soil in a strip running from Mr. Cuthbert's farm to Mr. E. Oakley's is better than the remainder of the Chertsey type. The writer finds the only difference is that the former is a little better supplied with humus.

Notes on Texture and Carrying-capacity of Weakly Podsolized Soils (c).

The soils of this group do not show a great deal of variation in texture, the most striking difference being due to the presence or absence of stones. These soils, on the whole, contain more coarse sand than the other soils of the low-rainfall area, the amount being highest up to 16 per cent. in the Seafield stony silt loam (1), the Lismore stony silt loam, and the Maronan stony silt loam. The Maronan stony silt loam is the coarsest in texture.

The sheep-carrying capacity ranges from 1 ewe to $\frac{1}{2}$ to $\frac{3}{5}$ ewe per acre. Cairnbrae carries $1\frac{1}{4}$ ewes, Seafield silt loam $\frac{3}{4}$, Seafield stony silt loam (1) almost 1, the Seafield stony silt loam (2) 1, the Lismore 1 to $1\frac{1}{4}$, Valetta almost 1, Maronan $\frac{1}{2}$ to $\frac{3}{5}$, and the Chertsey 1 ewe.

Skeletal Soils.

The skeletal soils are divided according to whether they are wind-borne or are water-sorted and according to whether they lie in the moderate- or high-rainfall area. This subdivision may be regarded as utilitarian rather than scientific.

skeletal soils (*a*).

These are young loess deposits in the moderate-rainfall belt.

(9) *Methven Silt Loam.*—The Methven silt loam is between 21 in. and 36 in. in depth and is free from stones. Humus extends to a depth of about 10 in., which is above the average for the group.

(17) *Wilson Silt Loam.*—The Wilson silt loam trends parallel to the river in the Highbank district. Its total depth is between 5 ft. and 6 ft. The soils in the vicinity of the gorge are doubtfully correlated with the Wilson silt loam.

(18) *Highbank Silt Loam.*—The Highbank silt loam is 3 ft. and more in thickness. The greater the distance from the river the less is the depth of loess. In places the humus layer is a foot or so thick; these are where there has been an accretion of soil by "blowing."

(19) *Carr Fine Sands and Sandy Loam.*—Soils of this type lie on a high-level terrace bordering the Rakaia River. They occupy a small area and have not been examined in detail.

Notes on Texture and Carrying-capacity of Skeletal Soils (a).

The principal types of skeletal soils (*a*) contain a small percentage of the coarse sand fraction and their clay-content is on the low side. The Highbank soils is a little finer in texture than the Wilson soil, and the Methven type finer still.

The carrying-capacity of the Highbank soil type is from $2\frac{1}{5}$ to 3 ewes per acre, and of the Methven soil $2\frac{1}{2}$ ewes.

SKELETAL SOILS (*b*).

These are water-sorted soils lying in the moderate-rainfall area.

(20) *Springfield Clay Loam.*—This type of soil forms a fairly wide belt extending from near the foothills through Methven and joining the Ashburton River ten miles above Ashburton Township. The deposits in this strip are probably older in age than the other water-sorted deposits. They mark an old flooding of the North branch of the Ashburton River. The total depth of soil and subsoil is in most places more than 3 ft. The texture of the soil is not uniform. As a whole, the soils are heavy in texture; those at the southern end are chiefly clay loams, whereas those at the northern end are mainly heavy silt loams.

(21) *Mayfield Silt Loam and Sandy Loam.*—The soils of this type in many places total more than 3 ft. in thickness. At the Hekeao Settlement and to the east of the junction of the south branch of the Ashburton River and Taylor's Stream they are about 30 in. On the east side of the north branch they are about 18 in. The texture of the topsoil is generally that of a silt loam, and the subsoil a silt loam or sandy loam. A few miles south of Rakaia Gorge the topsoil is a heavy silt loam and the subsoil a clay loam. The type is thus comprehensive. Farming experience shows that the higher ground at Hekeao Settlement (boundary marked by a dotted line) is better than the lower ground. Also the soil on the low flats below the Rakaia Gorge is much more fertile than the other soils.

(22) *Harrison Silt Loam.*—The Harrison silt loam lying near the foothills north-west of Methven has a total depth of more than 3 ft. The soil, and more particularly the subsoil, contain an ample supply of moisture. A point of difference with the usual run of soils is the fact that the topsoil is a very dark brown in colour and extends to a depth of 10 in. to 11 in. below the surface. There is some doubt to which group this type belongs.

(23) and (24) *Bowyer and North Sand.*—These types include sand deposits lying close to the rivers. The Bowyer sands are 18 in. to more than 3 ft. in depth, while the North sands are shallow—9 in. or so. The latter dry out badly in dry weather.

Notes on Texture and Carrying-capacity of Skeletal Soils (b).

If the sandy types are excluded, it can be said that the soils of this group contain a fairly high percentage of clay and a small amount of coarse sand.

Most sheep per acre are grazed on the Springfield clay loam, the carrying-capacity being $2\frac{1}{2}$ to 3 ewes. On the other types the areas are too small to get a reliable estimate. On the upper terrace on the Mayfield type at Hekeao Settlement, where some dairying is practised, a beast to 2 acres is carried.

SKELETAL SOILS (*c*).

This group comprises the young loess soils on the right bank of the Rakaia River and on the left bank of the Rangitata.

(10) *Lyndhurst Stony Silt Loam.*—The soil and subsoil average in total depth 18 in. Both are, in general, stony, but on the northern margin there are only a few stones. The soil of this type is more moist than those nearer the coast.

(25) *Barrhill Silt Loam.*—The loess from which the soil of the Barrhill silt loam is derived is as much as 15 ft. thick. The topsoil to a depth of 10 in. to 15 in. is dark brown to blackish.

(26) *Hatfield Silt Loam.*—The Hatfield silt loam ranges in thickness from 29 in. to 3 ft. and more, the shallowest depth being on the south-western edge of the strip.

(27) *Rakaia Silt Loam.*—The Rakaia silt loam has a total depth of between 18 in. and 19 in. On the average, the depth of silt loam in the strip following the Dorie Road is slightly more than in the strip closer to the Rakaia River (a dotted line on the map shows the division within this type). Near the junction of the Dorie Road with the main road the thickness is as much as 23 in. Farmers report that the two areas have different values for agriculture, but the soil difference appears to be insufficient for the creation of two separate types. The topsoil of the type is light coloured.

(28) *Ealing Silt Loam.*—The Ealing silt loam occupies a narrow strip along the Rangitata from Coldstream up to Carew. Its total depth is about 16 in. The soil and subsoil are coarser in texture than the soils of this group bordering the Rakaia River. They contain sand blown from the river.

Notes on Texture and Carrying-capacity of Skeletal Soils (c).

In the skeletal soils (*c*) the Lyndhurst, Barrhill, Hatfield, and Rakaia are the most important types. These soils, with the exception of the Lyndhurst soil, resemble in texture the Wilson and Highbank types. They dry out badly in the summer and take on the feel of a silt soil. This is most noticeable on the Rakaia silt loam.

The Barrhill soil type has a high carrying-capacity 2 to 3 ewes per acre. On the Hatfield type the carrying-capacity is round about 2 ewes and on the Rakaia type from slightly more than 1 ewe to $1\frac{1}{2}$ ewes. Lyndhurst soil carries $1\frac{3}{4}$ ewes on the stony land in the south-west end and 2 ewes in the north.

SKELETAL SOILS (*d*).

The skeletal soils (*d*) include the water-sorted soils of the low-rainfall belt.

(29) *Wakanui Clay Loam and Clay.*—This type occurs chiefly on either bank of the Ashburton River and on the left bank of the Hinds River. The total depth of soil and subsoil is usually more than 3 ft. No detailed mapping of these areas has been attempted—they include some small strips of shallow and of stony soils. The soils on the left bank of the Hinds are the heaviest in texture, being clays. The lower end of this strip—near Blackbridge—should possibly be classed with the meadow soils. In some areas the topsoil is lighter in texture than a clay loam, but the subsoils are generally clay loams. The Wakanui clay loam bordering the peaty clay loam near Eiffelton is blackish in colour and contains much humus.

(30) *Riverside Silt Loam.*—Only one area of Riverside silt loam has been mapped—on the left bank of the Ashburton River. The topsoil is darker in colour than the average of the soils of the plain and is free. The subsoil is compact. The total depth is more than 3 ft.

(31) *Coldstream Silt Loam.*—The Coldstream silt loam occurs on a low terrace bordering the Rangitata River. The total depth is 15 in. to more than 3 ft. During present-day north-westers loess is added to the topsoil. The topsoil—8 in. thick—is light coloured and the subsoil cream in colour. From this type should be excluded some strips of shallow stony silt loam.

(32) *Westerfield Silt Loam.*—The Westerfield silt loam, occurring only in the Westerfield district, is more than 3 ft. in depth. Its subsoil is a heavy silt loam. From the feel of the topsoil one would say that its texture was that of a silt.

(33) *Tinwald Stony Silt Loam and Silt Loam.*—The Tinwald silt loam occurs chiefly in the Tinwald and Rakaia districts. The total depth of soil and subsoil lying on the gravel is only about 13 in. Over much the greater area it is stony.

(34) *Greenstreet Sand Loam and Silt Loam.*—The Greenstreet sandy loam and silt loam is found in the Greenstreet and Laghmor districts and on the banks of the Hinds River. The total depth is 3 ft. The topsoil is generally sandy and the subsoil is a very sandy loam or fine sand.

(35) *Kingsbury Stony Silt and Silt Loam.*—The Kingsbury stony silt and silt loam lies to the south of Dorie. Its total depth is 11 in. to 20 in. The topsoils are light in colour and contain less than the usual amount of humus.

(36) and (37) *Hinds and Ashburton Sands.*—These types are located close to the rivers. The Ashburton sands are shallow, generally not more than 12 in., and the Hinds sands are usually more than 3 ft. deep. The sands below Dorie are classed with the Ashburton type, but there are areas of Hinds sands in them.

Notes on Texture and Carrying-capacity of Skeletal Soils (d).

There is more variation in texture in this group than in others. The Wakanui soils are the heaviest; at one locality the texture is that of a clay. The Riverside, Greenstreet, and Westerfield types contain much fine sand, and consequently the topsoils are all moderately free, the freest being the first mentioned.

High carrying-capacity—3 ewes—is obtained on the Wakanui, Riverside, and Coldstream soils. On the Tinwald type 1 to 1½ ewes and on the Greenstreet type 1½ to 2 ewes are carried. Judged by the wheat-yields, the carrying-capacity of the Westerfield type is equal to, or better than, that of the Greenstreet type.

MEADOW SOILS.

The meadow soils are formed where the groundwater is at or close to the surface. Their subsoils are bleached or stained with iron oxide.

(38) *Lowcliffe Silt Loam and Sandy Loam.*—This type occurs near the coast at Lowcliffe and at Willowby. The total depth of soil and subsoil is about 15 in. The subsoil, grey in colour, is a silt and silt loam in texture.

(39) *Eiffelton Clay.*—The Eiffelton soil type is more than 3 ft. deep. The subsoil, a clay loam in texture, is cream-coloured, except where stained with iron oxide. This soil is generally moist.

(40) *Blackbridge Silt Loam.*—The Blackbridge silt loam, located at Blackbridge, occupies a very small area. A profile is 9 in. blackish silt loam lying on 27 in. cream to light-grey silt loam. On this moist soil cocksfoot grows well.

(41) *Waterton Silt Loam.*—The Waterton silt loam stretches from Longbeach to Riverside near the mouth of the Ashburton River. Its average depth is about 18 in. The topsoil is a light-grey silt loam and the subsoil a grey to light-brown silt loam. Iron concretions are common in the subsoil. This soil was originally waterlogged, but is now well drained, and in dry weather might easily be mistaken for a silt.

(42) *Flemington Silt Loam.*—The Flemington silt loam is confined to a small area to the east of Flemington. The type is distinguished by the presence of a well-cemented iron pan at depths ranging from 10 in. to 17 in. Its subsoil is a fine sand or silt loam. The area covered by this type is not as great as shown on the map—there are patches within it where no iron pan is found.

(43) *Anderson Silt Loam.*—The Anderson silt loam occurs in the Flemington district. Its profile is 7 in. dark-brown (shade red) silt loam lying on 11 in. creamy-yellow silt loam and sandy loam. This type, being high in organic matter, is related to the peaty soils.

Notes on Texture and Carrying-capacity of Meadow Soils.

As with skeletal soils (*d*), there is a fair range of textures in the group—from clay to clay loam and silt loam. The most free soil is the Waterton silt loam, which contains nearly 30 per cent. of fine sand.

The carrying-capacities are: Lowcliffe type, 1 ewe per acre; Eiffelton, a cow to 1½ to 2 acres; Blackbridge, a beast to 2 acres; and Waterton, 1 ewe to 1½ ewes.

PEAT SOILS.

The peat soils have developed in low-lying areas in the lower course of the Hinds River.

(44) *Peaty Silt Loam.*—This soil occurs in a narrow strip to the north of Flemington. A profile is: 9 in. peaty silt loam lying on 15 in. reddish-brown silt loam. The amount of organic matter in the soil is below normal.

(45) *Peaty Clay Loam.*—This soil occurs in the left bank of the Hinds River and to the west of Eiffelton. A profile is: 10 in. blackish peaty clay loam lying on 23 in. bleached sand and sticky clay loam. In dry weather the topsoil becomes dry and powdery and pastures suffer probably more so than on other soil types. The soil is wetted again with difficulty.

(46) *Peat.*—Peat up to 3 ft. deep occupies the central portion of the slight depression west of Eiffelton. It rests on grey sands.

The carrying-capacity of the peaty clay loam is 2 acres per beast.

Soil Types suitable for Irrigation.

The writer, with only pedological data at his command, is not in a position to state which soil types should be irrigated. He can tentatively select types which are deficient in moisture at certain times of the year and of even surface and state whether on these any difficulties from the soil point of view will be encountered. What follows will be useful if the engineer and farm-management surveyor agree that any of the types in the groups the writer has tentatively selected can be irrigated successfully.

Irrigable soils are to be looked for in the low-rainfall belt, where it is not uncommon to see pastures badly wilted. The meadow soils, with the possible exception of the Waterton silt loam, are excluded, as these soils are generally moist and have a fairly high water-table. The Waterton silt loam is now well drained and the soil becomes dry in summer. Because of their low-lying position—nearness to the water-table and liability to flooding—some of the silt loams, clay loams, and clays of the skeletal soils (*d*), particularly those between the Ashburton and Hinds Rivers, may not be irrigated. It may be considered that the moisture status in the weakly podsolized soils (*c*) and skeletal soils (*c*), close to the border of the moderate-rainfall belt, is not sufficiently low to warrant irrigation. An answer to this point can be given by Mr. Beck, who has taken moisture-observations in these localities; in the meantime the writer classes these areas as suitable for irrigation. The surface of the weakly podsolized soils (*c*) slopes gently towards the sea and in detail is slightly uneven. The surface on the skeletal soils (*c*) on the right bank of the Rakaia is similar to that in the weakly podsolized soils except that here and there are sand-dunes covered with loess. There is, nevertheless, in this group a big area of land of fairly even surface. The skeletal soils (*d*) have the most uneven surface. Variations in texture on a type are reflected in the topography; for instance, a stony silt loam may form a low ridge on an even surface of silt loam. The Ashburton and Hinds sands have a fairly irregular surface, and, because of this and their position below the general level of the plain, will probably not be irrigated.

It seems reasonable, then, to discuss in relation to irrigation the following groups:—

Weakly podsolized soils (*c*).
Skeletal soils (*c*).
Skeletal soils (*d*) (greater part of).
Meadow soils (one type).

Texture.—The texture of the subsoil is important in irrigation, for if it is a clay the water-table may be raised by the water sufficiently to cause waterlogging, or the water may seep to lower ground and cause waterlogging there. In the Ashburton County the clay subsoils are confined to the Wakanui soil type occurring on the left bank of the Hinds, an area which may not be irrigated. A heavy soil is not ideal for irrigation as the water soaks into it with difficulty. Nor is a sand an ideal soil since it holds a small amount of water and has to be irrigated more often than a loam. It requires during the year more water than soils of heavier texture. A loam, silt loam, or sandy loam may be considered the best. The great bulk of the Ashburton soils and subsoils are silt loams. Both the topsoil and subsoil of the weakly podsolized soils (*c*), the skeletal soils (*c*), and the Riverside, Coldstream, Westerfield, and Tinwald types of skeletal soils (*d*) are silt loams. The Greenstreet topsoil is a sandy loam and silt loam and the subsoil a silt loam or fine sand. The Wakanui type is the only heavy soil—clay loams and clay. Thus practically all the soils and subsoils in the areas which may be suitable for irrigation are silt loams. Such soils are readily irrigated. Practical tests by the Lands and Survey Department at Seafield show that the soil, as regards texture, offers no difficulty. This is a shallow soil, but an experiment in an area with a deep, compact subsoil (Hatfield silt loam) showed that when 6 in. of water were applied the water which soaked through the topsoil was able to pass freely into the subsoil. The Greenstreet type—sandy loam on fine sands—may equally well be irrigated. There remains the Wakanui clay loam. This class of soil, even though the rate of soakage of water is slow, has been successfully irrigated in Australia.

Soluble Salts.—Soluble salts were determined in the subsoils from three localities.* The total soluble salts in the Ashburton soils are much less than in Australian irrigated soils free from any trouble with salts. The chlorine and sulphate radicles are present in smaller amounts and carbonates are practically absent, whereas in the Australian soils 50 parts per 100,000 are common.

Table V.—Soluble Salts in Ashburton Soils (expressed as Parts per 100,000 of Air-dry Soil).

Soil Type.	Location.	Depth, in Inches, below Surface.	Total Soluble Salts.	Cl.	SO_4.	$H.CO_3$.
Methven .. .. Silt loam ..	Callaghan, .. Methven	13–16	13	0·6	4·0	About 1 part per million.
Barrhill .. .. Silt loam ..	Cromie, ... Hatfield	8–11	23	11	5·5	About 1 part per million.
Silt loam ..	Hatfield	14–17	19	6	3·0	About 1 part per million.
Seafield .. .. Silt loam ..	Dromore .. Railway Station ..	8–11	17	3	2·5	About 1 part per million.

* Analyses by Mr. F. T. Seelye, of the Dominion Laboratory.

Since the water will penetrate freely in the soils the practice of irrigation will cause a diminution of soluble salts in the subsoil; the salts will be washed down into the gravel. Thus the salts in the soil will give no trouble whatever. Nor is it likely that any appreciable amount will be added by the irrigation water, for the rivers drain from areas of very high rainfall. To be certain on this point analyses are being made of the water of the Rakaia and Rangitata Rivers.*

Soil-observations, then, show all conditions are favourable for irrigation.

Experiments needed to determine Amount of Water required.

Two fundamental observations on the soil types required in irrigation areas are field-capacity and permanent wilting-point. Field-capacity is the maximum amount of water which a soil holds against gravity. There must be free drainage for a soil to be at field-capacity—a waterlogged soil is above field-capacity as it contains gravity water. Permanent wilting-point is the percentage of moisture in a soil when the plants wilt and do not recover. The plants wilt generally in the evening and do not recover next morning.

Vehmeyer and Henrickson, working in California, have found that when a soil is irrigated the water soaks downward to a certain depth, depending on the amount of water used. Determination of the moisture in this moist soil just after irrigation showed that all the moist soil, even that at the bottom of the wetted zone, was at field-capacity. If now a further amount of water is applied on the surface a further depth of the dry subsoil becomes moistened up to field-capacity.

Experiments conducted by the writer at Seafield, Fairton, Moronan, and Rakaia demonstrated that the soils quickly reach field-capacity after irrigation. Samples from any one experiment taken one day, two days, and three days after the application of water were all, roughly, the same in moisture-content.

Table VI.—Irrigation Experiments to determine Field-capacity.

	Seafield Irrigation Farm (irrigated 2 in. to 3 in. Water).			Seafield (2 in. Water).			Seafield (4 in.).			Seafield (6 in.).		
	Moisture (Oven-dry Basis).	Date, 1934.	Rain.	Moisture.	Date, 1934.	Rain.	Moisture.	Date, 1934.	Rain.	Moisture.	Date, 1934.	Rain.
Unirrigated	16·5	24/3	..	19·1	3/4	..	..	..	..	..	..	..
One hour after irrigation	..	24/3	..	..	..	..	..	..	..	..	..	..
One day after irrigation	..	25/3	..	..	4/4	..	..	..	..	..	..	..
Two days after irrigation	..	26/3	..	..	5/4	..	..	..	..	..	..	..
Three days after irrigation	26·2	27/3	0·10	26·0	6/4	..	26·9	9/4	0·13	27·7	12/4	..
Four days after irrigation	..	28/3	0·64	..	7/4	..	..	..	0·18	..	..	..
Five days after irrigation	..	29/3	0·06	..	8/4	0·14	..	..	..	..	..	..
Six days after irrigation	..	30/3	..	24·4	9/4	0·13	24·4	12/4	..	25·3	15/4	..
Seven days after irrigation	24·7	31/3	..	..	..	..	..	..	..	..	..	..
Eleven days after irrigation	..	..	..	..	..	..	..	..	..	..	..	..

Table VI.—Irrigation Experiments to determine Field-capacity—*continued.*

	J. Connolly, Fairton (6 in.).			Seafield (6 in.).			Barker, Maronan (6 in.).			Barclay, Rakaia (6 in.).		
	Moisture.	Date, 1934.	Rain.	Moisture.	Date, 1934.	Rain.	Moisture.	Date.	Rain.	Moisture.	Date.	Rain.
Unirrigated	22·7	12/4	..	18·5	20/4	..	18·8	2/5	..	24·9	24/5	..
One hour after irrigation	32·8	12/4	..	30·2	20/4	..	..	..	..	..	24/5	North-wester.
One day after irrigation	28·0	13/4	..	28·0	21/4	..	30·2	3/5	0·99	24·1	25/5	0·25
Two days after irrigation	27·9	14/4	0·1	27·2	22/4	..	..	4/5	2·63	25·8	26/5	..
Three days after irrigation	28·2	15/4	..	26·7	23/4	..	..	5/5	0·08	25·3	27/5	..
Four days after irrigation	..	16/4	0·30	26·1	24/4	0·06	30·5	6/5	0·14	25·2	28/5	..
Five days after irrigation	26·9	17/4	..	27·5	25/4	0·30	31·9	7/5	..	24·5	29/5	..
Six days after irrigation	26·6	18/4	0·10	27·5	26/4	..	30·2	8/5	..	24·1	30/5	..
Seven days after irrigation	..	..	..	..	..	..	..	9/5	0·02	24·4	31/5	..
								10/5	0·08			
Eleven days after irrigation	..	..	..	..	..	..	28·2	13/5	..	..	..	..

Barker, Maronan, 0 in. to 7 in.; others, 0 in. to 9 in.

Analyses by Mr. L. Andrew, Dominion Laboratory.

The field-capacity of 0 in. to 9 in. depths of three, and 0 in. to 7 in. depth of one (Maronan) is :—

Type.	Locality.	Field-capacity (oven-dry Basis).
		Per Cent. Moisture.
Seafield silt loam	Seafield Irrigation Farm	27·2
Seafield silt loam	School, Fairton	28·0
Hatfield silt loam	Barclay's Farm, Hatfield	25·0
Maronan stony silt loam	Barker's Farm, Winslow	30·3

* See Appendix B.

The method followed was to mark out on a flattish piece of ground an area 5 ft. by 5 ft., surround it with a tightly packed sod wall, and gradually pour on a total depth of 6 in. of water. Samples were taken with a soil-auger and the holes filled with soil from outside the plot. The results indicate that there are differences, though small, in the capacities of the widespread soil types. As is to be expected, the Hatfield soil holds less water than the Seafield soil, as the former contains more sand and less clay than the other. The figure for Maronan silt loam is surprisingly high seeing that the soil contains much sand and little clay. This needs to be checked, as rain fell during the time of the experiment. Field-capacity figures are required for the other types:—

Lyndhurst stony silt loam.
Cairnbrae stony silt loam.
Seafield silt loam stony phase (1).
Seafield silt loam stony phase (2).
Lismore stony silt loam.
Valetta stony silt loam.
Chertsey silt loam.
Barrhill silt loam.
Rakaia silt loam.
Wakanui clay loam.
Riverside silt loam.
Coldstream silt loam.
Westerfield silt loam.
Tinwald stony silt loam.
Greenstreet sandy loam.
Kingsbury stony silt and silt loam.
Waterton silt loam.

From the results obtained above, one would say it is likely that the skeletal soils (*c*), with the exception of the Lyndhurst soil, will have a low field-capacity—they will require less than the average amount of water to moisten them. It is necessary to decide on the depth to which the soils should be moistened. This is a matter on which the agriculturist can give a decision. Probably it will be necessary to know the field-capacity of the subsoils of these types.

Permanent wilting-point for the soil types is best obtained in the field. During a dry spell the moisture in the soil can be determined when permanent wilting sets in.

The experimenter can next find the depth of water which needs to be applied to bring the soil types from a dry condition—almost down to permanent wilting-point—up to field-capacity. Varying depths of water are tried on similar plots to those mentioned above.

The moisture-content of the soils can be obtained at intervals to find out how long an interval elapses before the soil drops from field-capacity to near permanent wilting-point. This gives the interval that can be allowed between irrigations. The interval on types with a silt loam texture will not be the same for all. It will be least on the skeletal soils (*c*), the Maronan, Westerfield, and Waterton soil types, these being the soils which quickly take on a silty feel in the dry weather. The depth to the gravel also has to be considered. Pastures on shallow soils will reach the wilting stage more quickly than those on deep soils, as their roots can draw only to a slight extent on the subsoil for moisture.

Fertility.

No specific information can be given as to methods of improving the fertility of the soils, but it may be as well to discuss present fertility, using the carrying-capacity as a base. The least fertile is the Maronan stony silt loam, $\frac{1}{2}$ to $\frac{3}{5}$ ewes per acre, and the best the Methven silt loam, Springfield clay loam, and Wakanui clay loam, $2\frac{1}{2}$ to 3 ewes per acre. Considered by groups, the best soils are the skeletal soils (*a*), (*b*), (*c*) and skeletal soils (*d*) for the most part, and the least fertile are the podsolized soils. The meadow soils, judged by their carrying-capacity and wheat-yields, have, on the whole, a good fertility. The differences in the moderate-rainfall belt must be mainly due to differences in the content of plant-foods—moisture variations do not seem to enter into the problem, except perhaps in the case of the Buccleugh stony silt loam between the Hinds and south branch of the Ashburton River.

In the low-rainfall area differences in moisture-content account to some extent for the wide range in carrying-capacity. The small number of sheep grazed on the shallow soils—Maronan, Seafield, and Valetta types—is partly due to the fact that there is little, if any, subsoil from which plants can draw moisture during dry weather, but, as stated previously, it is thought that the weakly podsolized soils (*c*) are low in plant-foods because in bygone days the fertile topsoil was blown away. Also a comparison of the Chertsey and Barrhill and Hatfield types shows up clearly that there is difference in plant-food status. All these soils have a fairly good depth of subsoil, which allows of storage of moisture that can be drawn in by the plants. As noted earlier, the Barrhill and Hatfield soils dry out fairly quickly. Thus the factor which determines the low fertility of the Chertsey soil—1 ewe against 2 to 3 ewes on the Hatfield and Barrhill soils—is not a lower moisture-content, but a lower plant-food status. It is plain that when the weakly podsolized soils (*c*) are irrigated a considerable rise in fertility can be brought about by the application of fertilizers.

Summary.

(1) More than three-quarters of the plain of Ashburton County receives an average of 28 in. of rain during the year. The rainfall is least at the mouth of the Rangitata, being probably less than 25 in. In most years there is a very low rainfall in March and February at Ashburton, and in November as well at Rakaia.

(2) The soil types which have been mapped are described. The soils are derived from loess deposits and from water-sorted beds resting on greywacke gravels. The water-sorted beds occur chiefly along the banks of the Ashburton and Hinds Rivers. Much the greater part of the plain is

covered with loess. The loess deposits are practically all silt loams in texture, but there are differences in the amounts of the various constituents—sand, silt, and clay. For instance, the silt loams bordering the Rakaia River and in the Maronan district contain a smaller amount of clay than the soils in the Seafield district. There are also variations in the depth of loess lying on the gravel—ranging from 9 in. to more than 3 ft. The water-sorted soils are chiefly silt loams, though the textures range from that of sands to clays. Some of the water-sorted soils, on account of their low-lying position, had at one time, and in some cases even now, a high water-table. The young loess deposits bordering the Rakaia and Rangitata Rivers and the water-sorted deposits, except those in low-lying positions, are classed as skeletal soils. They have suffered little leaching and are consequently the most fertile. The older loess deposits are classed as weakly podsolized soils—*i.e.*, they have suffered leaching and, consequently, are of low fertility. The least fertile division is the weakly podsolized soils (*d*), which have lost their original fertile topsoil by blowing some thousands of years ago. In one district—the Hinds—the fertility is at so low a stage that Waihi disease in cattle, due to a deficiency of phosphate, occurs. The low-lying soils, with bleached subsoils, are meadow soils. There is a small area of peat soils which have accumulated in depressions. From the carrying-capacity figures one is able to compare the fertility of the main soil types.

The soil map is the principal contribution the pedologist makes. It is the foundation for moisture-studies to obtain the duty of water and for research as to the kind and amount of fertilizers to use on the soil types and for studies on farm-management. The mapping is not regarded as final; it is advisable that officers of the Public Works Department conduct detailed surveys in any of the areas chosen for irrigation.

(3) The term "light plain land," popularly applied to Maronan, Valetta, and Seafield soils, is misleading if it implies that the soils are light in texture. These types are all silt loams and are, if anything, somewhat heavier in texture than some of the so-called heavy land. The term can only mean that there is a shallow depth of soil lying on top of the gravel and that the fertility is low.

(4) A tentative selection of soil types in the low-rainfall area which may be irrigated has been made. These are:—

Weakly podsolized soils (*c*), 315,500 acres.
Skeletal soils (*c*), 91,800 acres.
Skeletal soils (*d*), greater part of.
Meadow soils (one type), 13,700 acres.

(5) Practically all these soils have textures which permit irrigation water to penetrate readily into the subsoil. There are, generally speaking, no clay subsoils which would cause the formation of a high-ground water-table.

(6) The soluble-salts content of the soils is very low and will diminish with irrigation. The water which will be used for irrigation is thought to be low in soluble salts (samples are being analysed).*

(7) It is necessary now to find the field-capacity and permanent wilting-point of the soil types which may be irrigated. Field-capacity is the maximum amount of moisture which the soil holds against gravity and permanent wilting-point, the amount of moisture in the soil when permanent-wilting of plants has taken place. When irrigating, soils need to be brought to field-capacity, and irrigation should be done before permanent wilting sets in. The writer has determined the field-capacity on four types of soil, and the results show that the Hatfield silt loam holds the least moisture. It is likely that, with the exception of the Lyndhurst soil, the skeletal soils (*c*), more particularly the Rakaia silt loam, have a comparatively low moisture-holding capacity. The depth of water required to bring the soil of each type from a dry state near the permanent wilting-point up to field-capacity is needed. Moisture-figures should be taken after irrigation to find out the period which elapses before the soils reach permanent wilting-point. In the field it was noticed that the skeletal soils (*c*) and the Maronan, Westerfield, and Waterton soil types quickly dry out.

From all these data the duty of water can be obtained, and there is enough data to predict differences according to soil types; but one can only wait till the observations are all made before a statement can be made as to whether the differences are of practical importance.

Appendix A.

Soil texture is expressed in terms of the percentages of the fractions obtained in a mechanical analyses of a soil in the laboratory. The chemist determines in the soil the percentages of coarse sand, fine sand, very fine sand, silt and clay, these fractions each having a definite diameter, the greatest being the coarse sand and the least the clay with a diameter less than one twelve-thousandth of an inch. From these results the chemist can give to the soil a textural name.

The following is the table used by Mr. T. Rigg:—

Sands contain more than 70 per cent. of coarse and fine sand and less than 20 per cent. of silt and clay.
Silt contains more than 50 per cent. of very fine sand and silt and less than 5 per cent. of clay.
Loam contains more than 50 per cent. of very fine sand, silt, and clay, and less than 35 per cent. of very fine sand and silt.
Sandy loam contains more than 20 per cent. of coarse sand.
Silt loam contains more than 35 per cent. of very fine sand and silt and less than 35 per cent. of clay.
Clay loam contains more than 60 per cent. of very fine sand, silt, and clay.
Clay contains more than 60 per cent. of very fine sand, silt, and clay and more than 30 per cent. of clay.
Peat and peaty soils contain high amounts of organic matter; in peat soils organic matter amounts to two-thirds or more; in sandy or loamy peats to between one-third and two-thirds, and in peaty sand, loam, or clay to between one-tenth and one-third.

* See Appendix B.

A loam, as is well known, has a nice balance of all the fractions. The silt loam, which bulks large on the Ashburton Plains, has more of the silt and very fine sand fractions than has the loam.

Clays (containing more than 30 per cent. of the clay fraction) are very heavy soils which become sticky when wet.

APPENDIX B.

The following are analyses of samples of water from the Rangitata and Ashburton Rivers collected by Mr. T. G. Beck :—

Analyses (results expressed as parts per 100,000).

	(1)	(2)
Chloride Cl'	0·35	0·35
Sulphate SO_4''	1·2	0·6
Bicarbonate HCO_3'	3·5	3·5
Total solids	5·0	5·3

(1) Rangitata River. (2) Ashburton River.

The waters, which will be used for irrigation purposes, are very low in total dissolved solids.

RESEARCH SCHOLARSHIPS.

Two national research scholarships of an annual value of £100 were awarded during the year. The holders of the scholarships and the researches upon which they are engaged are as follows :—

Miss Phyllis Robertson, M.Sc., Victoria University College, Wellington : "Investigations of the Diamond Back Moth" ; and

Mr. F. B. Shorland, M.Sc., Victoria College, Wellington : "Investigations of the Vitamin-content of New Zealand Fish Liver-oils."

IMPERIAL AGRICULTURAL BUREAUX.

The Department acts as the New Zealand co-operating Department with the eight Imperial Agricultural Research Bureaux, whose headquarters are centred in Great Britain, and each of which has its own representatives in the Dominion. The local representatives deal with a large number of inquiries originating in New Zealand, which are despatched to the headquarters of the several bureaux. Each Bureau regularly issues summaries of all investigations proceeding in its own respective sphere in any part of the world. New Zealand investigators are therefore readily kept in touch with all findings which are being made in the researches in which they are interested. In addition, each Bureau has issued separate reports on matters of general and particular interest. These reports have proved of distinct value in New Zealand. Since their inauguration the activities of the Bureau have proved of inestimable value to New Zealand research workers through the ready means they have provided for maintaining contact and touch with investigations proceeding in all parts of the world.

MISCELLANEOUS INVESTIGATIONS.

Apart from the main research work which has been indicated in previous pages, the Department has rendered assistance to a number of industries and to other Departments in connection with a very wide range of matters of interest to the Dominion. During the year it has facilitated the tests arranged in connection with experimental shipments of pork-carcasses. These experimental lines have been sent forward for the expert opinion of Dr. Hammond, and Messrs. Davidson and Swain, who, in association with the Department's Liaison Officer, Mr. Nevill L. Wright, have prepared a detail report regarding the suitability of the carcasses in the consignment for the English trade.

Examinations of livers specially packed, wrapped, and chilled have been made from time to time for the New Zealand Meat-producers Board, which has been desirous of developing a trade in this class of meat by-products.

Chilled-beef shipments have been watched and assisted by the Department, which has made available its staff and experimental equipment for the purpose of making those observations and records which are very desirable during the early stages of this trade. The need for constant care and improvement in slaughterhouse hygiene, in the maintenance of proper temperature and gas conditions in the holds, warrant a close scientific supervision being made of, at least, selected shipments leaving New Zealand.

Further examinations have been made of fruit-carrying holds of overseas vessels which may be liable to transmit taint or flavour to either dairy-produce or meat. The Department is maintaining a supervision of the various methods which may be adopted to eliminate such taints.

Investigations as to the possibility of power of alcohol manufacture in New Zealand have also been made, and a brief report thereon is published in the *New Zealand Journal of Science and Technology.*

"NEW ZEALAND JOURNAL OF SCIENCE AND TECHNOLOGY."

The *New Zealand Journal of Science and Technology* has been issued regularly at two-monthly intervals. The *Journal* has included reports of researches carried out by the staff of the Department of Scientific and Industrial Research and other Government Departments, as well as from other institutions in New Zealand engaged upon research projects. Reprints from the *Journal* have been made extensive use of to convey the results of investigations to manufacturers and industrialists throughout New Zealand.

RESEARCH WORK AT CANTERBURY AGRICULTURAL COLLEGE, LINCOLN.

Wheat.—As in previous years, general work is being continued with observations and trials of wheats from every country, and further crosses are being tested.

One of the earlier crosses—known as Cross 7—is now available for distribution, there being 30 acres grown at the College and other areas on contract. This cross has the wind-resisting qualities of Tuscan, with stronger straw and more flour, of better baking-quality. It is suited to medium-class soils rather than heavy. It is notable as the first to be distributed of crossed wheats bred in New Zealand, and was bred at a time when little encouragement was being given to this work. It is hoped that this wheat will be known as College No. 7.

Of crosses of oats there are a number in hand, and, of these, one is distinctly promising, and with satisfactory trials this year may be multiplied next year. A reselection of Algerians is also under trial. Experiments are being made to test the effect on the germination of wheat of various dressings used for smut or bunt. Trials are also being carried out on thickness of seeding of the various varieties of oats.

Grass-breeding.—Extended trials, involving much time and work, are being conducted with first and second generation of plants grown from self-fertilized selections of cocksfoot, rye-grass, and hybrids. Similar trials with types of red clover are being made. Of the cocksfoot strains the best to date has been C. 23, which proved satisfactory for all the conditions under which it was tried. Unfortunately, like all our best leafy types, it is not a prolific seeder. It is expected to harvest a quantity of seed this year, but the amount, if any, available for distribution above the requirements for seed-production cannot be predicted.

Two strains of rye-grass are under the second year of trials, and if they prove satisfactory this season plots for seed-production will be sown. No names or numbers have been given these strains, which represent the first attempt to breed up a permanent strain of rye-grass as distinct from those available on the market, which are a collection of permanent types.

Among the red clovers there are several promising types, but no definite decision has been made in regard to their multiplication, though it is hoped shortly to announce the multiplication of a type of greater permanence than any clover at present grown in New Zealand.

Feeding-trials.—These are being continued with pigs, using any foods or combinations of food that may be suggested as suitable. Mangels and potatoes were tried last year as cheap winter feeds, but results are not yet available.

During the last two winters the dairy cows have been fed on a basis of so-much per gallon of production. The full report, when published, will contain valuable information, especially for those carrying on winter dairying.

Sheep are still being carried on the area set aside for demonstrating the value of rotational grazing. These sheep are used for winter-feeding observations in connection with wool and lamb production. Points of general interest now established are that it is possible with proper management—

(1) To carry on intensive sheep-farming on grass and maintain the sheep in good health; and
(2) To maintain and, indeed, improve the pastures at the same time. The poorer types are kept in check by the enforced eating-off of the early growth, and the better grasses and clovers are given a chance by the frequent spelling of the pasture.

Veterinary Work.—The work of this branch increases in range, in quantity, and in complexity each year. On the flock at Ashley Dene there are being made extensive and comprehensive observations and measurements of the effects of feeding on the condition of, and incidence of, disease among breeding-ewes. Most of the many troubles under observation are connected with losses of ewes before and after lambing, and with losses of lambs at all stages. Milk-fever among ewes before and after lambing, hitherto unrecognized, has been added to the list of untreatable and mysterious causes of losses. The number of calls for advice and help in the sphere of ordinary practice increases steadily.

A few metropolitan trials on sheep have been instituted, and more will be carried out when the special equipment can be provided. These should be both useful and helpful to research workers and, when interpreted, to the sheep-farmer.

Blood-analyses involving much work have also been undertaken. It is hoped that these investigations may throw light on some sheep-troubles, as well as aiding diagnoses.

Zoology.—Investigations of plant and animal parasites have shown that much more work of this nature is necessary. For example, to combat successfully internal parasites a fuller knowledge of their life-history in New Zealand must be known.

Farm-costing.—Investigations into farm-costing and farm accountancy continue. Results are difficult to estimate, but the increased interest of the farmers in this work is a healthy sign.

Farm Advisory Service.—Operations along the lines of previous years have continued and increased in regard to both farms under partial or complete control and request for advice and preparation of budgets. The method of this branch is based on the preparation not of a budget only, but on an estimate of the possible production of each farm. Advice is also given as to possible improvements, with special emphasis on the type of farming and stock as determined by the nature of the land, the management of the stock, and possible means of effecting economics. The productive-capacity of any farm is determined, and thus its true value is arrived at.

Engineering.—In conjunction with the Farm Advisory Service experiments are being made with irrigation on the Seafield Irrigation Farm. It is hoped, if funds are forthcoming, to carry on the experiments to a stage where a definite pronouncement in regard to irrigation in Canterbury is possible. This is especially desirable with an innovation of this sort to avoid the loss of money which so often results from attempting such schemes without the necessary preliminary investigations.

DOMINION LABORATORY.

The work of the year consisted almost entirely of chemical analyses and investigations undertaken for Government Departments.

The number of samples received in Wellington from the Departments were :—

Customs, 268 ; Police, 48 ; Geological Survey, 210 ; Main Highways, 286 ; Mines, 175 ; Health, 3,386 ; Post and Telegraph, 25 ; Research, 157 ; Public Works, 54 ; Railways, 60 ; Agriculture, 231 ; Defence, 12 ; Prisons, 135 ; Government Printing Office, 66 ; External Affairs, 26 ; Education Board, 18 ; other Departments, 42. In addition to these, 29 samples were received from municipal and other bodies and 428 from miscellaneous sources, a total of 5,656.

The totals for the branch laboratories were : Auckland, 3,124 ; Christchurch, 2,416 ; Dunedin, 1,190. Of these, the majority were milks submitted by the Department of Health, the numbers being 2,173, 1,957, and 895 respectively.

Customs.—The majority of the reports made to this Department were for use for tariff purposes. A considerable number of materials, including flour, cream of tartar, iodized salt, malt extract, and liquid paraffin, were analysed to ascertain if they complied with the regulations under the Sale of Food and Drugs Act. These analyses serve a very useful purpose, as by this means the importation of defective foods or drugs is prevented.

On the whole, the samples so analysed were found to be satisfactory.

Police.—In New Zealand, as in most other countries, increasing use is being made of scientific assistance in connection with criminal and other investigations.

This has been particularly the case during the year under review, as, in addition to the testing of various exhibits for poisons in cases of suspected murder and suicide, a very large number of diverse materials were examined in connection with criminal investigations. Various members of the Laboratory staff have been consulted from time to time by police officers in such cases where their special knowledge might be of assistance.

In Wellington strychnine was found in two poisoning cases, and in one carbon monoxide, and in another morphine. A number of exhibits were examined for the presence of habit-forming drugs. Several wines were analysed for alcoholic strength and the nature of the materials employed in their manufacture.

A number of samples of so-called "home brew" were examined in connection with sly-grog prosecutions.

Some counterfeit coins also were analysed.

At Auckland poisons found in cases of death were : lysol, nicotine (Black Leaf 40), strychnine, and veronal. In one case a child had died from taking several compound blaud pills containing in each $\frac{1}{30}$ grain of strychnine.

A number of drugs and solutions used in procuring abortion were examined.

A belt sold at a very high price for the treatment of rheumatism consisted of flannel plus $\frac{1}{4}$ oz. of sulphur.

Other cases investigated included examination of marks on accused's car in alleged negligent driving ; examination of a motor-car engine destroyed by gelignite ; examination of a bullet and a bullet-hole in a coat in a case of robbery ; comparison of brass-marks on jemmies with broken locks ; examination of metallic residues and ashes from a fire, for precious stones and metals, alleged to have been burnt ; identification of hairs on a razor alleged to have been stolen.

A large number of counterfeit coins were examined, and in one case the plant used for casting the coins. A number of genuine coins which had been contaminated with mercury were also examined. The mercury produced a pronounced alteration in weight and ring.

In a case of murder followed by the destruction of the body and belongings of the deceased by burning, a large number of exhibits were examined. They included burnt or charred bone, sacking, various clothing-fabrics, leather and nails from boots, rubber ware, artificial teeth with charred vulcanite adhering, small spheres of lead from bullets, portion of a smoker's pipe, and metallic fittings from clothing. For comparison purposes examination was also made of residues obtained by burning sheep together with articles, such as bullets thought to have been burnt with the body of the murdered man.

At Christchurch nicotine, strychnine, chloroform, and alcohol respectively were found in exhibits examined in cases of suspected poisoning.

A number of analyses were made of "Honeymead," which was found to contain 25 per cent. to 26 per cent. of proof spirit. The alcohol-content was equal to that of strong wine or cider.

At Dunedin strychnine was detected in three cases of human-poisoning and also in a case of horse-poisoning.

In a case of breaking and entering a considerable amount of work, largely non-chemical, was carried out. In the possession of the suspect was found a tire-lever on which was a small fragment of red paint. It was shown that the paint on the lever was similar in composition to paint on a door which had been forced. It was convincingly demonstrated by means of a low-power photomicrography that the marks on the door had been made with the tire-lever in question.

Department of Health.—Milk : A slightly larger number (7,721 in all) of milk-samples were examined than in the previous year when the total was 7,587. As will be seen from the particulars of the four centres they were, on the whole, not as satisfactory as in the preceding year.

Wellington : of 1,810 samples submitted from Wellington City, 13 were deficient in fat, 19 contained added water, and 12 were stale. Of the watered samples, 16 were obtained from the one vendor who was supplying shipping. With this exception the record is equally as good as that of the previous year, when of 1,667 samples 16 were deficient in fat, 3 contained added water, and 4 were stale. It is satisfactory to note that the milk-supply of Wellington City still maintains its high standard of quality.

From the country districts, which include Nelson, Marlborough, Wellington Province (except Wellington City), Taranaki, Hawke's Bay, and Gisborne, 886 samples were examined. Of these, 14 were deficient in fat and 12 contained added water.

Auckland: Of 1,744 samples from Auckland City 27 contained added water, 19 were seriously deficient in fat, 15 contained appreciable amounts of visible dirt, and 36 were stale (as shown by the reductase test). Of 37 other deficient samples, 12 were slightly below the standard in fat, 11 were somewhat stale, and 24 contained visible dirt.

The majority of the samples of stale milk were from small shops with poor facilities for storing milk. This indicates the necessity of making the provision of adequate storage a condition of licenses issued to milk-shops. These small shops also furnish two-thirds of the samples below the standard in fat, probably due to carelessness in not mixing the milk prior to sale.

From the country districts of Auckland Province 429 samples were obtained, of which 8 contained added water, 4 were seriously deficient in fat, and 5 were very dirty. Less serious deficiencies were: Low fat, 2; low solids other than fat, 3; and slightly dirty, 13.

Reductase tests of the milks from the Hamilton district have been made at Hamilton and have shown a very high standard.

After several years, in which warnings only have been issued for cases of visible dirt in milk, a number of successful prosecutions have been taken, and this has caused a marked improvement.

In the Auckland district milk is sometimes sold which is below the legal standard for solids other than fat, but does not contain added water. During the year 30 such samples were analysed, and in one case where the solids other than fat were 8·0 per cent. (legal minimum is 8·5 per cent.) a successful prosecution was taken against the supplier. This was an important decision, as it is often contended that it should be lawful to sell milk which is below the legal standard, provided it is sold as it comes from the cow. While this at first sight appears reasonable, it must be borne in mind that such milk is cheaper to produce than higher-quality milk and the seller accordingly has an advantage over the seller of the higher-quality milk.

If the sale of such sub-standard milk were allowed the tendency would therefore be towards a lowering of the average quality of the milk sold. The legal standard is a very reasonable one, and readily attained, as the average composition of milk sold shows. This average is—Fat 4·1 per cent. and solids other than fat 9·1 per cent., in both respects considerably above the legal standard. From the consumers' point of view it matters little whether poor-quality milk is naturally so or it has been made so by the addition of water. In the case mentioned above, the milk was equivalent to average-quality milk adulterated with 10 per cent. of water.

The number of samples containing added water has not decreased, and probably will not do so until the fines inflicted are heavy enough to make such adulteration unprofitable.

Christchurch: From Christchurch City and suburbs 1,364 samples were examined. The percentage not complying with the regulations was 7·2, which is higher than for 1933 (5·9 per cent.). This increase is accounted for by a considerable amount of adulteration with added water, which took place during the mid-winter period, when there was an acute milk-shortage. In other respects the supply calls for no special comment.

Of 593 samples obtained from the country districts of Canterbury (421) and from the West Coast district (172), 2 contained added water, 5 were deficient in fat, 21 were deficient in solids other than fat, and 2 slightly deficient in fat.

Dunedin: The number of samples (347) taken in Dunedin City was the lowest since 1929, and seems inadequate for proper control. The number could be increased to 1,000 and then would not be proportionately greater than the numbers taken in the other three centres. Saltpeter was detected in six samples purchased from two vendors. This is a very unusual form of adulteration, and the chemical was probably added as a preservative, though it would not be effective for the purpose. Three samples were deficient in fat, 1 contained added water, 3 were stale (as shown by the reductase test), and 8 were slightly below the standard in fat or in solids other than fat.

Of the 435 samples obtained in the country districts, 7 were deficient in fat and 12 were slightly below the standard in fat or in solids other than fat.

One hundred and thirteen samples from the Waipiata Sanatorium were the subject of a special investigation.

Water.—A total of 351 samples of water, mostly from existing and projected town supplies, were analysed in the four centres. At Auckland a special investigation was made of sea-water from beaches near the main-sewer outfall. None of the samples gave evidence of pollution.

Another problem of special interest was the treatment of Lake Pupuke (Auckland) with copper sulphate to kill a growth of ceratium, which was causing odour and flavour troubles in the Devonport water-supply. The lake holds 21,000,000 tons of water, and the copper sulphate was applied in the ratio of 0·3 parts per million, a strong solution being sprayed from a launch, running on parallel courses over the lake.

The rate of application was varied according to the depth. The treatment look ten days to complete and resulted in the entire destruction of the ceratium. The worst samples examined prior to treatment contained 1,000 ceratium per cubic centimeter. The average count was 400. Since the completion of the treatment samples have been examined regularly each month, and no trace of ceratium has been found.

Miscellaneous: A large number of various foodstuffs and drinks were examined. They included baking-powder, beer, bread, butter, cordials, cream of tartar, cream, cheese, coffee, coffee and chicory, egg substitute, essences, fruit, ice cream, jam, marmalade, liquors, margarine, mustard, mince-meat, sausage-meat, sugar, sweets, suet, and tinned fish. With few exceptions, these were found to comply with the regulations.

Of 349 samples of butter examined in the main laboratory and the three branches 15 contained water in excess of the maximum allowed (16 per cent.). No boric acid was found in any of the samples.

Several vinegars were wrongly labelled as malt vinegar; a number of the mince and sausage meats contained excessive amounts of preservative (sulphur dioxide), and several of the liquors were not true to label. One brand of cordial was found to contain saccharin. Some sugar had been accidently mixed with salt.

The jams, mostly of New Zealand manufacture, were all of very good quality. No added colouring matter was found in any of the samples. This is in marked contrast to jam sold before the Sale of Food and Drugs Act came into operation.

Red rubber hose used in piping beer was found to contain antimony compounds. Although the risk of poisoning would be very slight, it was recommended that its use be discontinued. In one town armenian bole, an iron-bearing clay, had been used for colouring meat-products. This was formerly allowed, but in recent years has been prohibited. Celery which had been sprayed with copper compounds as fungicides had a considerable amount of copper carbonate adhering to it when sold.

A large number of drugs was examined to ascertain if they complied with the requirements of the British Pharmacopoeia. They included liquid paraffin, castor oil, olive oil, citric acid, borax, glycerin, anæsthetic ether and chloroform, camphorated oil, tincture of iodine, lime water, lysol, Parrishes' food, and zinc ointment. With the exception of the camphorated oil, of which several samples were very deficient in camphor, the samples were found to be of satisfactory quality.

In addition to these, several preparations recommended for the treatment of obesity were examined for thyroid or other iodine-containing material. In no case was significant amounts of iodine found. They mostly consisted of well-known laxatives.

A number of samples of air taken in connection with the ventilation of various work-rooms and theatres, and also of the Hataitai Tunnel (Wellington), were examined during the year.

Mines Department.—Numerous prospectors' samples from all parts of the Dominion have been tested, chiefly for gold and silver, and occasionally for other metals. A number of samples were examined for manganese, for which a demand exists abroad. Many coal-samples from the State coal-mines and other localities have been analysed. Mine-airs from collieries have been examined as required by the inspection staff of the Department for noxious and inflammable gases.

Some further work is in progress regarding the utilization of New Zealand coal for gasmaking. The excessive swelling of some coals limits their usefulness. Investigations in previous years have shown that blending with non-swelling coals, including the brown (sub-bituminous) coals, overcomes this difficulty, but blending is laborious on a works scale. It has been suggested that exposure to the air by storage for several months prior to use might be a solution, and the Department and the Laboratory are co-operating in a series of experiments with typical coals.

Government Stores.—As in the previous year numerous samples were analysed in connection with the purchase of stores by the Post Office, Public Works, Stores Control, and other Government Departments. These included bricks, cleaning-compounds, corrugated iron, creosote, cyclostyle inks, shellac, soap, tent-material, rivets, typewriter-ribbons, paint, white-lead, and red-lead. The information provided by the analyses of the paints has been most useful to officers in charge of Government contracts. Several investigations were made of cases of corrosion of materials.

Gas-inspection.

The gas-supplies of the four main centres and principal towns have been regularly examined for calorific value, purity, and pressure, and were found of satisfactory quality.

Research.

Fuel.—The progress of coal research in Great Britain and, as far as possible, in other countries is carefully followed by the Director of the Laboratory, especially research dealing with the addition of pulverized coal to fuel oil for oil firing, and with hydrogenation of coal to produce petrol and other oils. The Fuel Chemist of the Laboratory, who formerly worked under the Coal Research Association, is in Great Britain at present and is making a special study of hydrogenation.

Spray Research.—The analytical work required by the officers of the Plant Research Station for their investigations has been continued during the year. Many samples of tobacco have been examined to determine the proportion of nicotine in different varieties grown in New Zealand, and its distribution in the leaf and stem of the plant. Experiments carried out in the field in regard to spray-coverage under various conditions has called for numerous determinations of minute amounts of arsenic and lime.

Soil Research.—Numerous type soils have been analysed for the Geological Survey Department.

Fruit.—Arrangements are in hand for chemical examination of New Zealand grape-fruit each month throughout the season. The storage of passion-fruit and its transport overseas are also under investigation.

Phormium (New Zealand Flax).—A more fundamental examination of the chemistry of phormium than has hitherto been possible is about to be undertaken.

Ragwort.—The work on the toxic principle in ragwort (*Senecio jacoboea*) growing in New Zealand has been continued. A substance evidently identical with the alkaloid *jacobine* was isolated and the formula found to differ from that previously assigned to it. An investigation as to its physiological action is in progress at the Veterinary Laboratory, Wallaceville.

Investigations were continued in connection with moosoi oil from Samoa. Resins from certain species of *Agathis* have been examined. Different members of the genus *Dacrydium* have been examined with a view to finding chemical means of distinguishing between the timbers.

Examination has been made of some newer methods for testing bituminous materials employed in highway-construction. Members of the staff have, as required, carried out investigations of analytical methods and have prepared papers on various aspects of their work.

Advisory and Consulting Work.

The Director of the Laboratory and other members of the staff have frequently been required to advise regarding chemical subjects or to report on industrial processes.

GEOLOGICAL SURVEY BRANCH.

REPORT OF DIRECTOR (DR. J. HENDERSON).

During the year ended 31st May, 1935, the Director, in the course of official business, visited Kaitaia, Hikurangi, Maratoto, and Waihi in the North Island, as well as Top Valley, Mahakipawa, and Reefton in the South. He also accompanied Messrs. C. R. Holzworth and J. W. Holden, metallurgical engineers of the staff of H. A. Brassert and Co. (London), on visits to the Parapara iron-ore deposits and to the coalfields of Westhaven, Westport, Greymouth, and Huntly. A short account of observations made in the Marlborough district is included in this report.

Mr. M. Ongley completed the examination of the Eketahuna Subdivision and mapped a small area in the Wairarapa Subdivision adjoining on the south. A black-and-white map of the district and a *résumé* of its geology forms part of this report. Mr. Ongley also prepared a digest of such available reports and abstracts on water-supply as are likely to be useful in considering how the water-supply of dairy farms and factories may be improved. He visited Taranaki and Waikato to study water-conditions in those districts.

Messrs. H. E. Fyfe and J. Healy continued field-work in the Amuri Subdivision, in which district the rock-exposures are in some respects exceptionally favourable. The proper understanding of its rather complex stratigraphy and structure will clear up several difficulties at present retarding New Zealand geology.

Mr. J. H. Williamson finished mapping the Naseby Subdivision. He had already been two field seasons in this district and in last year's annual report had published an account of its geology and a map showing the distribution of the formations. Though Mr. Williamson has now resigned from the Geological Survey he will write the report describing this district.

The greater part of Mr. E. O. Macpherson's time was occupied in making special geological investigations of areas to be or being examined geophysically. A *résumé* of his work is published elsewhere. He also began the detailed mapping of an area in Southland and briefly reported on the oil-bore near Limehills.

Dr. L. I. Grange, in charge of the soil survey, carried out reconnaissance work in Ashburton, Levels, and Southland Counties, and, assisted by Mr. N. H. Taylor, continued the detailed mapping of the soils of Waipa County. Mr. Taylor also studied the underground water-conditions of the Hamilton Basin and the Piako district. The reports of these officers have been or will be published elsewhere.

This year the key map of New Zealand showing the state of the geological survey is republished. Maps covering an area of 19,162 square miles on the scale of a mile to the inch, and maps of 845 square miles on a scale of two miles to the inch, have already been issued, and those of a further 1,777 square miles are in the press. In addition, several areas, containing approximately 12,000 square miles, have been surveyed and mapped in detail.

The twenty-ninth annual report of the Geological Survey and an important palæontological bulletin entitled "The Fauna of the Reefton Beds (Devonian), New Zealand" were the only publications issued during the year. Officers contributed several papers to the *New Zealand Journal of Science and Technology*. These were: "The Gum-land Soils of North Auckland," "Ironstone Soils of North Auckland," and "Rhyolite Sheet Flows of the North Island," by L. I. Grange; "Bentonite and its Occurrence in New Zealand," by H. E. Fyfe; "Quartz Lodes of Oturehua, Nenthorn and Macraes Flat," by J. H. Williamson; and "Manawatu Gorge," by M. Ongley. In the "Proceedings of the Fifth Pacific Science Congress" there appeared "The Coal Resources of New Zealand" and "Lead and Zinc Resources of New Zealand," by J. Henderson; and "The Sequence of Molluscan Life in New Zealand," by J. Marwick. A paper entitled "Some New Zealand Tertiary Mollusca," by J. Marwick, was printed in Vol. 21 of the "Proceedings of the Malacological Society of London."

Mr. G. E. Harris made two large drawings and eleven block drawings for photolithic reproduction, and prepared twenty-six field sheets for officers. Work for the geophysical parties took a large part of his time. He drew twenty-three tracings for sun-printing and coloured 215 prints.

The usual periodicals and exchanges were regularly received and listed for the library. A heavy correspondence on subjects connected more or less with the work of the survey was attended to, and many samples of rocks, minerals, and ore were examined.

EKETAHUNA SUBDIVISION.

(By M. ONGLEY.)

Comparatively little is known about the geology of the south-east of the North Island, and occasionally important discoveries there are rumoured. In particular, the question of oil keeps cropping up, for it is known that throughout the east coast there occur beds of dark mudstone that smell of oil and yield oil on heating, and also that there are many springs from which issue salt water, mud, inflammable gas, and traces of oil. These have naturally caused people to believe that productive oilfields will be found, and half a dozen wells have been drilled at great expense. To see if there is any evidence whether this work should be continued, if so, how it can best be done, and to get information about other possible resources by pursuance of the systematic geological survey of the country, work was begun in east Wellington in 1930 in what is called the "Eketahuna Subdivision" of Wairarapa. This area extends along the east coast from eight miles north of Cape Turnagain to five miles south of Castle Point and inland to the Tararua Range, including 1,700 square miles. In the field-work the writer has had the assistance of Mr. J. H. Williamson in 1930–31, Mr. H. E. Fyfe 1931–32, Dr. J. Marwick at times in 1932 and 1933.

Topography.

Along the east of the subdivision is the sea and along the west the Tararua Range, 5,000 ft. high at the south, descending to 1,000 ft. at the north. The grain of the country is parallel with the Tararua Range—that is, the main ridges run east of north parallel with the mountains. In the north they are spaced eighteen, twenty-two, and thirty-five miles east of the Tararua Range, and are the Waewaepa Range (2,500 ft. high), Puketoi Range (2,500 ft.), and Te Awa Putahi (1,900 ft.). These ranges, however, diminish to the south, and at ten to twenty miles from the northern boundary merge into the plateau country which comprises the greater part of the subdivision. This plateau is dissected into ridges 1,500 ft. to 1,000 ft. high and extends to the coast.

At the west is the Tararua Range, rising from the alluvial deposits of the west coast eastward at an angle of 5° to 10° to 1,000 ft. at the lowest point, and falling steeply eastward at 40° to the lowlands at the east of the mountains and 300 ft. to 500 ft. above the sea. From there the country rises again gently to the east in a long, continuous slope for fifteen miles to the crest of the Waewaepa Range, 2,500 ft. high, thence dropping steeply to the narrow upper Makuri-Mangatoro depression, 1,000 ft. above sea-level. Next it rises at 20° for two miles to the east as a limestone dip-slope of which the high edge forms the crest of the Puketoi Range, 2,600 ft. high. East of the limestone escarpment the country continues fairly even at about 1,200 ft. to 1,500 ft. for eight miles to the eastward, but drops at the change of rock near the Akitio River. East of the river the country continues at about 1,000 ft. with higher ridges of hard rock, and rises again into another block, 1,000 ft. to 1,200 ft., eight miles wide.

This northern part of the subdivision is fairly regular, but the south differs somewhat. In the south-west spurs diverge north-east from the Tararua Range and form the Tawhero Ridge, which drops from 3,000 ft. to 1,500 ft., and the Mount Bruce (1,600 ft. to 1,200 ft.) ridge. East of these are the two parallel limestone ridges that run through Snowden (1,822 ft.) and Rangitumau (1,983 ft.) and, six miles farther east, the sandstone ridge through Tintock (1,755 ft.). Two more sandstone ridges seven and fourteen miles farther east run through Manawa (1,376 ft.) and Tanawa (1,500 ft.) and converge six miles to the southward in Tinui Taipo. Near the southern boundary jagged peaks of greywacke form the hills known as the taipos—Mangapakeha and Clyde.

Unlike many parts of New Zealand the subdivision has no plain along the coast, the only extensive plains being adjacent to the highlands along the west. In the south-west the lowland of the Wairarapa plain fingers up the rivers, flanked by many terraces; and, similarly in the north-west, flats and terraces flank the Manawatu and its tributaries. Extensive terraces occur along the rivers and also along the coast south of Castle Point.

The subdivision is minutely dissected by a complex pattern of streams with wide infilled valley-bottoms through which the entrenched streams meander in narrow courses. Many of the streams flow with the grain of the country: among those flowing east of north are the Mangamaire and Mangarapa in the north-east, and the lower Tiraumea, Mangatainoka, Makakahi, and Mangahao in the north-west; and flowing west of south are the Whareama, Taueru, and Kopuaranga. These, with many smaller tributaries, bring out the north-north-east grain of the country and show how far the drainage has adjusted itself to the structure. Apart from these, the rivers in the east—Waimata, Akitio, Aohanga, and Mataikona—flow in wide meanders, roughly, south-east from the interior to the coast and are apparently rejuvenated consequents.

The coast is nearly straight, parallel with the grain of the country, except where hard limestone forms capes, as at Turnagain and Castle Point. Cliffs, behind which hills rise 1,000 ft. above the sea, edge much of the land and are being rapidly cut back past the stable position, so that wide belts are slipping to the sea. This is in spite of the fact that the land is protected somewhat by an inter-tidal eroded platform up to 30 chains wide along the coast. The rivers break the continuity of the high coast and have wide drowned mouths infilled and subsequently entrenched about 20 ft. North of the river-mouths are short stretches of sand-beaches.

A conspicuous coastal feature is the terrace that extends from Castle Point south for six miles. It is half a mile wide, 50 ft. to 400 ft. above the sea, and is capped in parts with fossiliferous marine sand and gravel.

Structure.

The subdivision in the north consists of five long strips trending north-north-east. The western strip, mostly outside the subdivision, is the Tararua Range, an anticline rising from the alluvial plains of the west coast at an angle of 5° and dipping eastward to the lowland at 30°. From the Tararua Range to the crest of the Waewaepa Range, eighteen miles to the east, is a wide syncline, called the Pahiatua syncline, with a short west limb and a long gentle east limb broken at the Tiraumea River by a fault. East of Waewaepa Range is a fault down-throwing to the east thousands of feet. East of the fault the country rises for two miles as a homocline capped by a limestone dip-slope to the crest of the Puketoi Range. East of the crest the homocline continues for another eight miles to the Mount Cerberus-Ossa Ridge, where it is also broken by a fault, along which the country to the east was dropped. This fault is splintered, and the Mount Cerberus-Ossa block has a jagged eastern margin and a low, transverse structural depression crossing it at Weber in a west-of-north direction. The next belt, eight miles wide, forms the large Akitio syncline, compound in parts and formed of Tertiary beds lying between Cretaceous blocks. East of the Tertiary syncline is a Cretaceous high block seven miles wide, folded into an incipient syncline in the middle at the north and flanked on the east at Cape Turnagain by a Tertiary eastward-dipping monoclinal fragment, evidently the remnant of another Tertiary syncline.

The south part of the subdivision is not so simple. In the south-west, splinters diverge from the Tararua Range enclosing wedges of Tertiary beds in the angles between the blocks of greywacke. The greywacke blocks are also closely faulted longitudinally; the narrow pieces gently tilted west have Tertiary strips and patches low on the slope or in the fault angle. In Mikimiki Survey District this type of structure is on so small a scale as to give to the map a striped appearance suggestive of a grid-iron. The most easterly escarpment of these small blocks runs through Mounts Bruce, Munro, and Hansen, and lines up with the Tiraumea fault on the east flank of the big Pahiatua syncline.

Two miles east of this greywacke escarpment is the well-marked fault trace of the 1855 earthquake, which has been followed south from Mauriceville twenty-five miles to the Waiohine River. This part has been described by Mr. B. Iorns, of Masterton, in the *Wairarapa Daily Times* of 24th September, 1932. At its north end the ancient greywacke crops out west of the railway opposite Dryer's Rock Road, indicating that the 1855 uplift of 5 ft. to 10 ft. was merely a slight movement along an old fault on which the geology indicates movements aggregating thousands of feet.

At Dryer's Rock this fault, which trends 33° east of north from Palliser Bay for sixty miles, turns to the east and was followed for three miles trending 75°. This transverse fracture probably joins the Mount Marchant fault and then, by another transverse fracture, extends to the Mangatoro fault on the east of the Waewaepa Range. East of the 1855 fault-trace the limestone is folded into a syncline two miles wide which caps the ridges. Farther east the limestone is broken and let down by a fault, from which it rises again eastward in a dip-slope to the Rangitumau crest. This westward-dipping homocline extends five miles farther east; next there is a stripped greywacke ridge two miles wide separated by a strip of Tertiary a mile wide from a larger area of greywacke. The structure of this part is complex and has not been cleared up altogether. Jurassic, Lower Cretaceous, and Upper Cretaceous rocks are present, the two lower sets exceedingly complicated, broken, and crushed, the upper set folded regularly.

Tinui (Maunsell) Taipo, as already mentioned, is the south end of the big northward-pitching Tertiary syncline surrounded on the east, west, and south by Cretaceous beds. A mile and a half to the east a thin strip of Tertiary is faulted into the Cretaceous, and east of that the Cretaceous high block stretches four miles to the east; beyond this another block of Tertiary a mile and a half wide is faulted down along the coast. At Castle Point a fault in the Tertiary lets down the younger beds.

In most parts of New Zealand the covering strata are successively younger nearer the coast; in the Eketahuna Subdivision, on the contrary, the series are successively younger inland. The youngest series, the Mangahao Series, is confined to the foot of the Tararua Range, the next youngest (Petane) extends five miles east of the range, the next (Te Aute) extends to the east coast in patches, but the continuous outcrops are west of Puketoi Range—that is, twenty miles from the Tararua Range. This distribution may be due to the method of deposition or to the nature of the folding and faulting; and the distribution of the Te Aute Series favours the second cause.

Another feature is that the basal beds of the Tertiary sequence are of different ages. In the Akitio syncline they are Weber and Ihungia, to the west Tutamoe, and farther north-west Te Aute. Also in the eastern half of the subdivision Cretaceous formations underlie the Tertiary, and in the western half the Cretaceous is missing.

Stratigraphy.

The subdivision, though close to Wellington, has not been a happy hunting-ground for geologists. It has remained unexamined for so long because it does not present simple problems, abundant fossils, continuous sections, or attractive outcrops. In the circumstances it is not thought that this first detailed survey will have correctly solved all the difficulties; and accordingly this account of the stratigraphy cannot be regarded as final. The Tertiary beds are generally poorly fossiliferous, and in large areas no fossils have been found. The Cretaceous beds contain fewer fossils, and the older beds fewer still; indeed, fossils in them are exceptional. Thus much of the work is based on lithology, continuity of beds, and inference.

Tararua Series.—The greywacke formations of the North Island are commonly referred to as Trias-Jura; but the evidence for this is disproved in the South Island, where it originated, and without doubt there are many separate formations in the greywacke. Within this subdivision we have greywacke formations with Cretaceous fossils, a greywacke formation with Jurassic fossils, as well as an immense mass of greywacke without known fossils and probably belonging to several formations. In this report the great mass of unfossiliferous greywacke is lumped into the Tararua Series. It forms the Tararua Ranges along the west of the subdivision and contains beds of conglomerate, which indicate that more than one formation are present. Besides the conglomerate beds already mentioned the formation includes the usual alternating beds of greywacke and argillite in which the greywacke beds are 1 ft. to 2 ft. thick and the argillite beds 3 in. to 6 in.

This formation contains many veins of quartz, up to 30 ft. wide, but none is known of value.

Taitai Series.—Correlated on lithology with the Taitai Series of Waiapu Subdivision, the rocks here classified as Taitai consist of massive dark sandstone with very little argillite and many beds of coarse igneous conglomerate. They form the jagged peaks, called "taipos," in the middle of the southern part of the subdivision, which stand out so distinctly towering over the landscape. The rocks are generally very much crushed and shattered, but are not nearly as indurated as the greywacke of the Tararua Series. They resemble more the rocks of the Waewaepa Series and may belong to that formation; but until fossil evidence is found they are being kept apart. The association of these Taitai rocks with very crushed black argillite is similar to the relation of the Taitai to the Tapuwaeroa Series in the Raukumara Peninsula.

The greywacke in the north-east of the subdivision contains thick beds of coarse igneous conglomerate, and is accordingly placed in the Taitai. In the north it does not differ much from the surrounding greywacke that contains *Inoceramus*, which is classed as Raukumara. The boundary is tentative.

Waewaepa Series.—In three places the fossil identified by Dr. Marwick as *Buchia* has been found, and accordingly the beds at these three places and the associated beds are grouped together and called the Waewaepa Series of Jurassic age. But the structure is so complex, and the lithology so indistinctive, that there is no certainty that the Waewaepa Series as mapped is a unit; in fact, it is almost certain that it is not, for at two of the three places where the fossils were found the normal sediments were interrupted, in one place by dyke rocks, not actually found in place, and at the other by surface lava. Yet the greywacke beds above and below are so similar, and the structure so complicated, and these particular parts so barren that it is deemed best not to endeavour to subdivide them.

Raukumara Series.—The beds that contain *Inoceramus bicorrugatus*, the distinctive fossil of the Raukumara Series of Waiapu Subdivision, are correlated and classed as the Cretaceous Raukumara Series. Only in one place—that is, in Aohanga Survey District, along Mataikona River—do the beds crop out in a continuous section, and there they are 5,000 ft. thick; their lower part terminates against a fault.

Tapuwaeroa Series.—Parallel with and overlying the beds of the Raukumara Series are thick beds of conglomerate containing *Ostrea lapillicola*, the characteristic fossil of the Cretaceous Tapuwaeroa Series of Waiapu Subdivision. Similar beds extend half a mile up the Mataikona Stream dipping 70° westward and exposing beds 2,500 ft. thick. Similar strata, more crushed and slickensided, occur in Mangapakeha Survey District, but the *Ostrea* was not found in them. They contain thin bands crammed with *Aucellina*, rare *Belemnites*, and thin layers of sandstone thickly felted with fibres of *Inoceramus*.

Mangatu Series.—Above the Tapuwaeroa Series is a thick set of beds of fine grain and light colour, evidently the waste from a reduced land. In Mataikona River they crop out half a mile along the stream dipping 75° westward and so exposing beds 2,500 ft. thick. They are certainly thicker, for they are faulted off at the top. Many of the beds are fine siltstone, stained black with carbonaceous matter. These decompose with a stong, yellow efflorescence coloured like sulphur, for which it is sometimes mistaken. When freshly broken these beds smell of oil, they are not easily wetted by rain or in the stream, they give off gas in quarries, and on heating yield gas and oil. They have accordingly been regarded as evidence that the district is an oilfield. These dark beds are associated with other fine beds without carbonaceous matter, almost white in colour. Similar beds occur in many parts of the district and are classified as Mangatu. So far in the subdivision no Tertiary fossil has been found in any of these beds, and they may all belong to the Cretaceous; but in other parts of New Zealand similar beds have been found to be Tertiary, and so parts of the Mangatu may also belong to the Tertiary. Hence the Mangatu Series is classified in this report as Upper Cretaceous and Lower Tertiary.

Weber and Ihungia Series.—The first beds above the Mangatu Series are white siltstones similar to, and evidently formed as, a rewash of the Mangatu. They occur only in places, and from their outcrops near Weber have been called the Weber Series. They grade into darker mudstones that underlie the Tutamoe and are accordingly correlated with the Ihungia Series (Lower Miocene) of Waiapu Subdivision. In Waiapu the base of the Ihungia is everywhere faulted off, and the succession at Weber is probably the normal sequence.

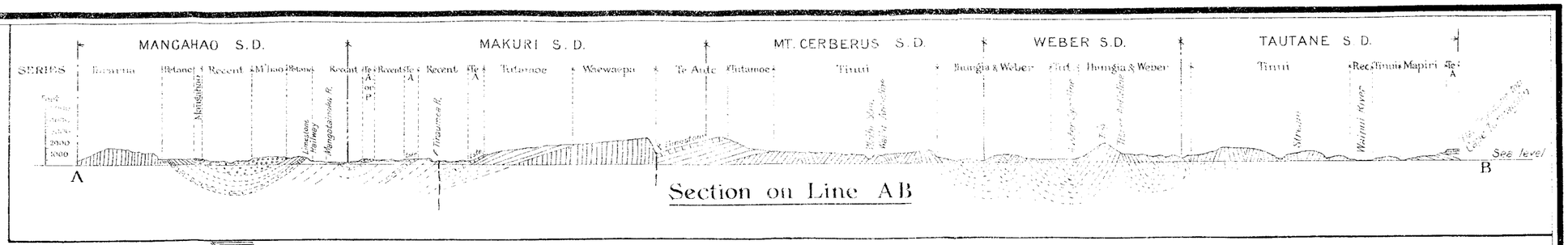
In several places the light, lower beds (Weber) contain what are called "fucoids," but the age significance of these is not known.

The base of the Weber is in places a bed of greensand 4 ft. thick; but in many places there is no good marker between the Mangatu and the Weber, and as the beds are similar in many respects it is likely that the mapping of these formations is confused.

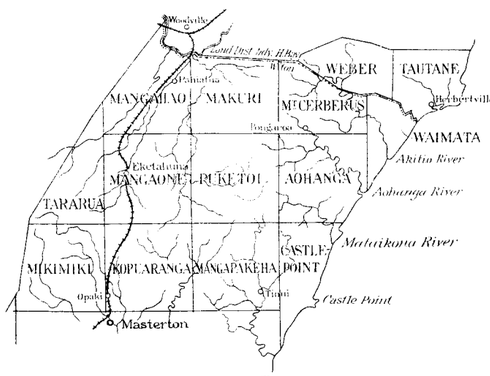
Tutamoe Series.—Above the Ihungia, or resting on older formations, occurs a formation with many thick beds of coarse sandstone and beds of conglomerate with the sturdy thick fossils characteristic of the Tutamoe Series of Waiapu. In many places similar sandstone beds are found without any fossils and are tentatively classed as Tutamoe. The top of the Tutamoe is definite in places and in other places vague. For instance, in Mangapakeha Survey District a cliff-forming band of hard, white pumiceous sandstone 20 ft. thick affords an easily mapped boundary between the Tutamoe beds below and the overlying set. But in the north-west part of the district, in Mangahao and Makuri Survey Districts, the sandstone formation is very thick, without fossils, and without definite horizon-markers; it has all been tentatively classed as Tutamoe, but probably parts of it are younger. In Mangapakeha Survey District, where the upper boundary is definite, the Tutamoe beds are 2,500 ft. thick; in Weber Survey District they are more than 5,000 ft. thick.

In some places, as in the south-east part of Weber Survey District, no discordance is found between the Tutamoe Series and the underlying Ihungia; in the north-west part of the same survey district there is angular unconformity, an eroded surface, and a basal conglomerate. In many places the Tutamoe rests on older formations with no Ihungia present.

Mapiri Series.—Parallel with the beds of the Tutamoe is a bed of white tuffaceous sandstone, 10 ft. to 20 ft. thick, which makes conspicuous cliffs and ridges over a large area in Mangapakeha, Puketoi, and Aohanga Survey Districts and separates the underlying Tutamoe from the overlying beds, which are called "Mapiri." There is a similar bed marking the boundary in Tautane Survey District, in the north-east of the subdivision, and a similar bed forms the base of the Mapiri Series in



Section on Line AB



KEY MAP
SHOWING SURVEY DISTRICTS

Scale
MILES 10 5 0 10 20 30 MILES

LEGEND

- RECENT AND PLEISTOCENE
- PLIOCENE: Mangahao Series; Petane Series; Te Aute Series
- MIOCENE: Waihoki Series; Mapiri Series; Tutamoe Series
- OLIGOCENE: Ihungia and Weber series
- LOWER TERTIARY AND UPPER CRETACEOUS: Tinui Series
- LOWER CRETACEOUS: Tapuwaeroa Series; Raukumara Series
- JURASSIC: Waewaepa Series; Taitai Series
- LOW MESOZOIC OR PALÆOZOIC: Tararua Series
- Faults
- Anticlines
- Synclines

Compiled from data obtained from the Lands and Survey Department. Additional surveys and geology by M. Ongley, J. H. Williamson, H. E. Fyle and J. Marwick of the N. Z. Geological Survey

GEOLOGICAL MAP OF

EKETAHUNA SUBDIVISION

NAPIER AND WAIRARAPA DIVISIONS, HAWKE'S BAY AND WELLINGTON LAND DISTRICTS

SCALE
Mile 1 0 1 2 3 4 5 6 7 Miles Km 1 ½ 0 1 2 3 4 5 6 7 8 9 10 11 12 Km.
1 : 253440

G.E.Harris, del. 1935.

the type locality at Mapiri Point in Wairoa Subdivision. Although many white tuffaceous beds occur higher in the sequence the lowest seems to be an excellent indicator. Above it, apart from the many beds of white tuffaceous sandstone, the rocks are mostly light-coloured mudstone full of tuff. Near the middle of the subdivision these beds fill the Tawhero syncline and are 1,000 ft. thick without a top. In the west they were not separated, as the thick basal tuffaceous sandstone was not found but probably the upper part of the beds mapped as Tutamoe should be Mapiri.

Waihoki Series.—Above the Mapiri Series is a thick set of coarse sandstone beds similar to the underlying Tutamoe Series. They are exposed in the cuttings along Waihoki Valley Road in the north-east part of Puketoi Survey District, and are called the Waihoki Series. Similar sandstone above the Mapiri Series in the south-east and north-east parts of Kopuaranga Survey District are also included in the Waihoki group, and probably some of the high beds in Mangaone and Mangahao Survey Districts mapped as Tutamoe will be found to belong to the Waihoki Series. In Kopuaranga Survey District they are 3,000 ft. thick without top. In the north-east, in the McCartie syncline, where Mapiri beds have not been recognized, the sandstone along the axis is probably Waihoki.

Opoiti Series.—In the mudstone that underlies the limestone of the "castle" at Castle Point Dr. Marwick found fossils indicating that the beds belong to the Opoiti Series of Wairoa Subdivision. The formation covers too small an area to show on the map.

Te Aute Series.—Resting indifferently on all the older formations and extending from the east to the west and from the north to the south of the subdivision is a formation containing two thick beds of limestone that form the strong ridges and extensive dip slopes that make many conspicuous features of the landscape, including the "castle" at Castle Point, the cliff at Cape Turnagain, the crest of the Puketoi Range, &c. The limestones contain many pebbles and broken shells and grades at places into conglomerate. The distribution of the beds, the transgression on all the older formations, and the conglomerates show that these beds mark an important marine transgression, which Dr. Marwick has correlated with the Te Aute of Hawke's Bay. In Makuri Survey District these beds are 2,500 ft. thick.

This group of beds forms the base of the Pliocene.

Petane Series.—Above the Te Aute Series is another set of beds consisting chiefly of mudstone, but containing at its base beds of conglomerate and pebbly limestone. A rich fossil locality in Mangahao Survey District on the Manawatu River was examined by Dr. Marwick and correlated with the Petane Series of Hawke's Bay. The same beds occupy the central and part of the west side of the Pahiatua syncline as shown on the map. They appear to be 1,000 ft. thick.

Mangahao Series.—Above the Petane Series is a set of beds totally different in nature consisting of beds of white pumiceous claystone and sandstone interbedded with poor coal and carbonaceous shale up to a foot thick and overlain by thick, coarse poorly cemented greywacke conglomerate. These beds are well exposed in the Mangahao River above the Tararua Road and are called the Mangahao Series. They extend north and south close to the east side of the Tararua Range; and the coaly beds in them, standing vertical in the north, have been taken for thick coal-seams. The overlying conglomerate, 150 ft. thick, is considerably younger than the pumiceous beds; but as neither contains fossils, as they occur together, and as the two together are not 200 ft. thick, they are classed together in the Mangahao Series.

Recent.—The Recent deposits include the gravels and sands of the beaches and terraces. North of the river-mouths the sand forms small areas of dunes, and some of it is climbing over the hills into the next valleys. Near Pahiatua there is a layer of pumiceous tuff on the surface, and in some of the valley bottoms the fine pumice sand has built small terraces.

Economic Geology.

Petroleum.—One important question concerning the subdivision is whether it is likely to produce payable oil. The indications—the black mudstone, the oil-smelling rock, and the gas-emanations—have been known for years. In addition, now we know something of the structure. The black shale, oil-smelling rocks, and gas belong to the Mangatu Series of the Upper Cretaceous. These are well exposed in many places, and nowhere is there anything in the nature of a seepage. Unless, therefore, the beds that are hidden differ importantly from the beds exposed this absence of seepage is strongly against the suggestion that oil has accumulated in the way necessary to form an oilfield. The structure of the subdivision, too, is not favourable. The beds have been not so much folded as faulted, and big anticlines like those those in Wairoa Subdivision have not been formed. Moreover, in the structurally high blocks the covering strata have been stripped off by erosion, so that any producing-beds, reservoir-beds, and retaining-beds have disappeared. There remain the smaller anticlines in the large synclines as favourable structures possibly containing petroleum.

Rock Products.—In the west of the subdivision the greywacke mountains and hills, and the gravels derived from them, afford abundant excellent materials for making roads and for working in concrete and bitumen. The Cretaceous rocks are much inferior, but have been used at points far away from the greywacke. In the Tertiary in the north-east and south-east the low Tertiary limestone is used, but in many places no good rock occurs. The maps show the nearest outcrops of greywacke. The Mangahao Series, as mapped, contains thick beds of coarse greywacke conglomerate.

Pumice Sand.—In the Mapiri Series are extensive beds of consolidated pumice sand. In the Mangahao Series similar beds, mostly clay and fine sand, occur close to the railway. In addition to these, recent terraces in the streams near Eketahuna consist of fine pumiceous sand.

Sands.—Besides pumice sands coarse dune sands are fairly extensive on parts of the coast remote from the railway. The Tertiary sandstone also is extensive and can be easily got in places remote from the railway. On the railway a thick bed of coarse, loosely cemented sandstone forms big cliffs two to three miles south of Eketahuna. This has been found suitable for use as a moulding-sand. A smaller deposit of finer sand is cut by the railway six miles north of Masterton.

Limestone.—In the Waewaepa Series marble occurs in a thin bed south of Eketahuna. In the Mangatu Series argillaceous limestone containing 70 per cent. $CaCO_3$ is fairly widespread. In the low Tertiary limestone, with over 90 per cent. $CaCO_3$, occurs in small amount in the north-east, and in fair quantity in the south-east where it is used as road-metal. A little is ground for agriculture. The Te Aute Series contains a great supply of high-grade limestone in all the parts shown on the maps, but so far has been worked only at Mauriceville and to a very small extent at Makuri. The Petane Series, too, contains a fair amount of limestone generally crammed with greywacke pebbles. Altogether, the district is abundantly supplied with limestone.

Clays.—Clay and claystone have been burnt for bricks and road-metal in several places and can be had nearly everywhere. Light, nearly white, claystone is widespread in the Mangatu Series.

WAKAIA SUBDIVISION.

(By E. O. Macpherson.)

In connection with geophysical studies, and as time permitted, about 140 square miles of the subdivision was geologically mapped in detail. This work was done in the Wakaia, Wendon, and Chatton Survey Districts. The rocks of this district lie between the Otago schists to the north and the Hokanui Series to the south, and therefore occupy a position of considerable interest and importance.

Physiography.

North-south mountain-ranges separated by broad valleys are the dominant land forms. In their northern part the mountains reach elevations around 3,500 ft. and merge northward into the Old Man Range, but southward the crests become progressively lower and at their southern end are about 1,200 ft. The ranges consist of metamorphic rocks, and the intervening valleys are occupied by younger sediments. The master streams—the Whakaea, Waikaka, and Otama—are adjusted to the softer sediments along the valleys and flow southward into Mataura River.

The topography is mainly controlled by the fault pattern, for the longitudinal ridges are eastward-tilted fault-blocks with dissected fault-scarps defining their western edges, and the valleys between are fault-angle depressions along which remnants of the softer covering strata are preserved. The principal deformation is thought to have taken place during the late Tertiary. The land-forms were later modified by long-continued erosion during standstill periods in the general uplift of the region, and at least three arrested cycles of river-erosion can be readily traced throughout the district.

Stratigraphy.

Recent and Pleistocene.—The gravels, sands, and silts of the flood-plains are the youngest accumulations of the subdivision, and these, with the terrace gravels, slope deposits, and the loess covering much of the surface, make up Recent and Pleistocene deposits. The loess consists of fine-grained angular particles of silt and sand, the considerable range in grain-size being characteristic. The texture is open, and typical exposures have well-defined vertical joints. This material was deposited on all uplands and varies in thickness from 1 ft. up to 30 ft. Obviously this deposit was not laid down by water, and is believed to be glacial dust deposited by wind.

Maori Bottom Beds.—Rusty gravel containing pebbles and cobbles of schist, graywacke, and quartz outcrop along the main valleys. These are post-deformational deposits, and the fragments of metamorphic rocks they contain were derived from the rising fault-blocks and distributed by the major streams. In places the Maori Bottom beds contain lignite seams.

Chatton Series.—Marine sandstones, clay, glauconitic sandstones, and limestone outcrop over a wide area in this subdivision. The distribution is controlled by the major north-south faults, and the beds outcrop as long narrow strips along the fault valleys. In many places they are obscured by Maori Bottom and younger sediments. These beds are of Ototaran age. Their lower contact with the quartz conglomerates can be studied down the Whakaea River one mile below the township on the eastern side of the valley. The section here shows a gradual transition, from quartz conglomerates to fossiliferous sandstone. In the Otama Valley there may be a thick lignite seam at the base, but whether this seam should be included with the marine beds or the underlying terrestrial beds cannot yet be decided.

Apparently the Ototaran sea transgressed over a land of low relief, for these marine sediments are everywhere; fine and coarse basal members were not seen.

Welshman Series.—Underlying the marine beds is a group of terrestrial beds containing quartz conglomerate, quartz sands, light-grey clay, lignitic clay, and seams of lignite. These are well exposed in Welshman Gully, which enters the Whakaea from the east about a mile and a quarter below Wakaia Township. Their distribution in the district is controlled by the north-south fault-system, and, in general, they are preserved along fault-angle depressions.

These deposits were laid down mainly as valley train and lagoonal beds in broad river valleys and the sediments were derived from a land of low relief. With the overlying marine beds, they are considered to have been deposited before major faulting disrupted this region.

Their age is not known, but they are obviously older than Ototaran and may even range to the Upper Cretaceous. They are tentatively correlated with the quartz conglomerates of Otago Central and are possibly the southern equivalent of Williamson's Hogburn Series.

This group contains the main lignite reserves of the district and is gold-bearing in places.

Clinton Series.—This group of argillites, fine and coarse greywakes, and conglomerates occupies a small area on the east bank of the Mataura, about four miles east-south-east from Riversdale. They also outcrop about a mile farther east in the basin of Okapua Creek. They are bounded on the north at both localities by the intrusive igneous mass described below, and on the south by Tertiary beds unconformably overlying them and by Recent gravels. Though indurated and decidedly jointed, they show no trace or schistose structure.

These rocks are tentatively placed in Ongley's Clinton Series (Carboniferous), which is exposed about thirty miles to the east-south-east along the general strike and on the northern edge of the same great structural depression, where it occupies the same relative position between the sub-schists and Mesozoic strata. Fragments of fibrous shell, resembling *Inoceramus* and possibly from the *Maitaia* occurring at Clinton, were found, but no other fossils. These fragments are abundant in the rocks near the igneous contact two miles and a half south of Pyramid Bridge.

Tuapeka Series.—This group of metamorphic rocks forms the basement complex of the region: quartzites, schists, sub-schists, phyllite, argillite, greywacke, and fine conglomerate are represented. In general, the degree of metamorphism increases northward toward the Otago schist region and decreases southward toward the Jurassic and Triassic rocks of the Hokanui Series.

The general strike is east-west or near this direction, but there are many strong local variations. These rocks are folded along east-west axes, the dips on the flanks of the folds are not everywhere high, and apparently the folds are not tightly compressed.

Their age is problematical. They contain no fossils, but since they occupy a position between the Otago schist to the north and Clinton beds of Carboniferous age to the south are probably older than the Carboniferous.

Igneous Rocks.

Vesicular Basalt.—A flow of lava, occurring along the toe of the fault-scarp which bounds the east side of Waikaka Valley, was followed from a point one mile and a half north of Waikaka Village to beyond the lignite mines, and may continue in this direction for several miles farther. The thickness of the flow is possibly 10 ft. and its maximum width about 10 chains. The lava is dark-coloured basalt and was injected through the lignite and quartz conglomerate and flowed over red and grey clays, which contain plant remains. In places these clays have been altered into porcellanites and the lava has picked up quartz-sand, quartz-pebbles, and resin from the lignites and associated beds. Fragments were seen which had ropy flow lines and scoriaceous surfaces. The flow is over-lain by wind-blown loess.

The lava, though connected with a strong north-south thrust fault, possibly was not actually injected up the major thrust plane and may have reached the surface along a subsidiary parallel fault or an east-west tear fault transverse to the major north-south fault.

At the lignite pit on the east side of Whakaea Valley, one mile south of Argyle Homestead, fragments of vesicular basalt were seen, but it is not certain if these masses are in places or have been carried from the nearby lignite pit. If they come from the pit, they most likely occur as dykes in the Maori Bottom lignite; if they are in place they were poured out over a surface of the Maori Bottom.

Further evidence on the age and distribution of lava was obtained from seismic studies, two miles north from the above locality and along the same fault line. Here a formation with a velocity of 9,000 ft. per second (about 5,000 ft. per second more than the velocity of the Maori Bottom gravel) was located 90 ft. below the surface. The boundary relations of this formation from the seismic profiles strongly suggested a concealed flow; apparently the rock flowed over a Maori Bottom surface and was buried by younger gravels.

At Happy Valley, in the Whakaea Valley and southward along this same fault-line, profiles were studied with a magnetometer in an attempt to outline a deep lead. This work showed that a line of high magnetic anomalies was disposed in an east-west direction, transverse to the north-south thrust fault. This suggests that a dyke had been injected along an east-west tear fault, transverse to the main north-south fault.

From the above evidence it appears that the basalt injections are younger than the Maori Bottom.

Otama Intrusive.—Igneous rocks occupy approximately thirty square miles in Wendon, Otama, and Chatton Survey Districts. They extend eastward from the Mataura River to beyond Waikaka Stream and reach almost to Waikaka Village. The western boundary is defined by the alluvium of the Mataura River and extends southward down the river from Pyramid Hill for about two miles to a point where the igneous rocks are in contact with hornfels, quartzites, and altered argillites of the Clinton Series. Northward from Pyramid Hill igneous rocks outcrop along the main road to Wakaia, and eastward from this road, almost to Wendon school. An obscure contact with metamorphic rocks can be seen toward the head of a small stream that crosses the road south of the school. From this locality the northern boundary of the intrusive mass continues eastward into Otama Valley and crosses from this valley into Waikaka Valley about three-quarters of a mile north of Wakaia Hill. Along

the east side of Otama Valley the igneous mass is disrupted by a north-south thrust fault which involves a strip of marine Tertiary sediments. This strip divides the igneous mass into two portions. The rock outcrops for half a mile east of Waikaka Stream and probably extends farther beneath loess, gravel, and Tertiary marine beds. Along the south boundary the mass is in part in intrusive contact with the Clinton beds, in part overlain by Tertiary beds, and in part concealed by river-gravels.

The intrusion is elongated in an east-west direction. The longest dimension is about eight miles, but to the east, south-east, and west the contact with the invaded rocks is obscured by younger beds, and the true east-and-west dimensions are probably much more. The greatest width in a north-south direction is four miles.

Petrographic work was not done on these igneous rocks, and the rock-names used here are merely field names, intended to convey general impressions. The rocks range from gabbros, diorites, and subordinate more basic segregations, to light-coloured granites with pinkish feldspars. Pegmatites, and possibly aplites, are also represented, and several large quartz lodes, one 100 ft. thick, containing much disseminated pyrites, traverse the igneous mass.

The distribution of these rock types within the intrusion were not studied in detail, but the impression gained is that belts or zones of dark and light coloured rocks extend parallel with its longest dimension; the dioritic rocks appear to lie on the outer margins and the granitic tend to occur in the central parts. More definite east-west zones of light-coloured fine-grained rock with few ferromagnesian minerals traverse the mass, and with these the quartz-pyrite lodes are connected.

From this it appears that a dioritic magma separated into several differentiates and that the early dioritic differentiate was intruded, along east-west lines, by the later more salic differentiates. The different rocks probably represent successively ejected phases and illustrate a growing siliceousness of the magma. The light-coloured fine-grained rocks and quartz lodes are the end-point of the intrusive episodes.

Five or six quartz lodes, enclosed in igneous rock, outcrop along the east side of the Otama Valley. These strike approximately east-west and dip north or south at high angles; similar lodes, with approximately the same attitude, outcrop on the western boundary of the intrusion along the Mataura River. These quartz lodes show on the surface as brownish cellular rust-bands from which the pyrites have been leached. Deeper in the mass the quartz contains much disseminated pyrites. The lodes are sheared in an east-west direction and the quartz is brecciated and recemented with lighter-coloured quartz. Seven samples assayed were found to contain no gold or silver.

The contact between the invading and invaded rock was not studied in detail, owing to the obscurity of all known contacts. Close to the contact it is difficult to distinguish the igneous rock from the altered sediments, and apparently there is assimilation and contamination. The quartzites are silicified, the argillites altered to hornfels, and at most contacts the rocks are veined with quartz, though the original bedding and induced structures are not obliterated. The invaded rock is sheared and brecciated close to some contacts and dips away from the intrusive at high angles.

The time of intrusion can be placed only within rather wide limits. The invaded sediments are older than the Triassic and Jurassic of the Hokanui Series and younger than the Otago schists, and are tentatively correlated with the Clinton Series of Upper Palæozoic age. Again, pebbles from a wide range of plutonic rocks occur abundantly in late Triassic conglomerates of the Hokanui group. Thus the Otama igneous mass was probably intruded between the Carboniferous and late Triassic.

The igneous rocks themselves are jointed and fractured and have pronounced east-west shears, but no gneissic or schistose structure. On the other hand it could not be strongly maintained that the invaded rock was affected by dynamic metamorphism to a greater extent than the invading rock.

Geological Structure.

Block-faulting after the middle Tertiary is the obvious structural control of this region; the earlier foldings and faultings, which affected the basement rocks, will not be discussed. The major faults trend a few degrees east of north, dip eastward generally at high angles, and have throws measurable in thousands of feet. They have disrupted the region into longitudinal blocks with dissected fault-scarps facing west and more gentle eastward-tilted back slopes. The eastern sides of the main valleys—Whakaea, Stony Creek – Otama, and Waikaka Valleys—are defined by major north-south faults. These faults are upthrusts, and along the fault-angle depressions or structural valleys Tertiary and younger sediments are preserved.

The age of faulting is post-Ototaran, for these beds and the underlying quartz conglomerates are involved. But the movement has been progressive, possibly with long periods of quiescence, followed by periods of movement, for Maori Bottom gravels (Pliocene) are also overturned and over-ridden by quartzite and semi-schist. A subordinate group of north-south faults also occur, but these do not extend so far or have the large throws of the major ones. These subordinate faults occur along the east side of the Whakaea Valley, about one mile west of the main fault, and along the same valley below Wakaia Township. Another extends from Winding Creek south to the Pyramid Stream. The strike of the fault is almost parallel with the major fault along this valley and about a mile west of it. Its scarp was traced almost continuously from the headwaters of Wendon Stream, except where offset by transverse faults, to Pyramid Creek. Its scarp faces eastward—that is, in the opposite direction to the scarp of the major fault—and between these two opposed scarps is a trough-like valley filled with younger sediments.

The dip of the fault-planes of these subordinate faults was not observed—regional evidence suggests that the fault planes are vertical or dip steeply westward.

A third group of faults, with a general east-west strike, offset the major and minor upthrusts. These are tension breaks or tear faults, their direction of throw varies from north to south, and there is probably also some horizontal displacement along them.

AMURI SUBDIVISION.

(By H. E. Fyfe and J. Healy.)

From December, 1934, to May, 1935, 350 square miles were mapped within the Kaitarau, Puhipuhi, Mount Fyffe, Greenburn, and Hundalee Survey Districts. This area is bounded by the sea from Oaro mouth to the Washdyke, and extends inland for an average distance of ten miles; within it are those portions of the Seaward Kaikouras accessible by way of the major streams that drain that mountain mass.

Structure.

The closely folded anticline, consisting probably of Taranakian conglomerates, with axis sub-parallel to the coast and extending from a point a mile east of Razor Back Trig. to a point about a mile west of Waipapa Homestead, is obliquely truncated by a fault that extends from half a mile north of Waipapa Point to the west end of Priam Flat. At Corner Hill, where this fault is joined by one that reaches the coast at Okiwi Bay, the Amuri limestone is thrust over the conglomerates to the east, a zone of amygdaloidal basaltic rock being involved in the faulting. Amuri limestone forms a series of hog-backs between these sub-parallel faults from Corner Hill to the point next north of Okiwi Bay, and a small strip of vertical Clarentian rocks outcrops along the fault north from Okiwi Bay.

The lenticular Patutu greywacke block is fault-surrounded. The high-angle fault, which enters the district two miles south-west of Razor Back Trig., apparently continues to the lower reaches of the Seaward Valley, where it joins, or is obliquely truncated by, a fault that reaches the coast at Half-moon Bay, and determines the lower Puhipuhi Valley. Sub-parallel with this fault is the major north-north-east-trending fault at the eastern base of the Seaward Kaikouras, and between them is the closely folded Puhipuhi syncline of Clarentian and Tertiary rocks that outcrop from the Hapuka to the Clarence at Waiau-toa Homestead.

Where the Waimangarara issues from the base of Mount Fyffe the major Seaward Kaikoura fault meets the fault that extends west-south-west by way of the Lottery and Hanmer Streams to the upper Waiau-uha.

Kaikoura Peninsula is an upwarped portion of the earth-block that, south of Oaro, forms the Amuri Bluff anticline and the Hawkswood Range.

The Hundalee highlands are fault-bounded on the west as well as on the east.

Along a low-angle westward-dipping thrust in the south branch of the Clinton, half a mile upstream from the junction with the north branch, the greywacke rocks are thrust about 300 ft. over terrace gravels that correspond roughly with the 200 ft. terrace cycle.

In the vicinity of Waiau-toa Homestead and just south of the Hapuka, a little north-west of Grange Road, are young fault-scarps or "earthquake rents" attesting movement in Recent times. But the fault from the eastern base of Mount Fyffe to the upper Waiau-uha shows the most extensive activity, ranging throughout the period between the formation of the 200 ft. terrace to the present time.

Geology.

Pre-Cretaceous Rocks.—The only identifiable fossils so far obtained from the greywackes are *Buchia* and *Inoceramus* fragments. Possibly some of these rocks are of Cretaceous age, though lithologically they are unlike any of the definitely Cretaceous beds so far mapped within the subdivision. The rocks containing these fossils are believed to overlie unconformably an older, possibly Triassic, series associated with pillow lavas, the break being marked by a widespread igneous conglomerate that contains acidic plutonic rocks and rare pebbles of the pillow lava.

The rocks are much folded and faulted and at many localities in the Seaward Kaikouras are altered to protomylonites and mylonites as a result of movements during the Hokanui orogeny. The Kaikoura orogenic movements have highly sheared and fractured the greywackes, especially near faults, and in the Seaward Kaikouras the younger fractures are in general oblique to the banding of the protomylonites.

Simple and complex shearing, which simulates the stratification of original bedding, is often induced in the massive greywacke. At some localities this shearing is transverse or oblique to the original bedding, and at other localities follows it.

Cretaceous Rocks.—The only fossiliferous Cretaceous rocks mapped during the season crop out in the Wharekiri Valley, where they are fault-involved among the pre-Cretaceous rocks, and whence they extend, by way of the Puhipuhi Valley, to Long Creek, a tributary of the Hapuka River. They consist of minor conglomerate bands interbedded with indurated banded sandstones and mudstones, overlain by a massive indurated sandstone containing minor pebble-beds. Dr. Marwick has identified *Dimitobelus superstes* (Hector) from a conglomerate apparently from the lower beds of the banded sandstones and mudstones; this indicates a Clarentian age for these sediments.

The indurated sandstones of the core of the anticline at Kaikoura Peninsula are unlike any of the Piripauan rocks of the Amuri Bluff section and resemble the uppermost sandstones of the Clarentian beds in the Hapuka section. At the peninsula the Clarentian beds are overlain by the concretionary saurian sandstones and sulphur-stained argillaceous sandstones that correspond to the upper Piripauan beds of Amuri Bluff. Thus a considerable thickness of the lower Piripauan sediments is missing from the peninsula. No section showing the complete sequence of Clarentian rocks has been observed, the contacts with the older rocks being faulted. At Mororimu Stream all the Piripauan rocks are missing and the Tertiary sands and flint-beds rest on the Clarentian rocks, an insignificant conglomerate band marking the contact below which the sandstones contain *Inoceramus* fragments.

Tertiary Rocks.—Sandstones, interbedded with flint-beds that grade to nodular flint-masses, more or less intimately mixed with the chalk marl, overlie the Clarentian rocks at Mororimu Stream. Flinty limestones crop out on the east wing of the Kaikoura anticline, but are not so abundant on the west. At all localities the chalk marl associated with the flint grades up to the typical Amuri limestone.

Dr. Finlay, on foraminiferal evidence, assigns an Eocene age to the chalk marl and Amuri limestone.

The phosphatic band interbedded between two limestones at Kaikoura Peninsula is regarded as the equivalent of the phosphate-band that at Amuri Bluff, and elsewhere overlies the Amuri limestone. In the coastal section just south of Oaro mouth, and at the mouth of the small stream a quarter of a mile south of the Okarahia, the phosphate-band is the basal member of limestones that could well be the equivalent of the upper limestone at Kaikoura. In specimens submitted by Mr. Osborne (Vacuum Oil Co.) from 15 ft. and 40 ft. above the phosphate-band near Oaro mouth, Dr. Finlay has recognized foraminiferal fauna he considers probably Upper Ihungian (Miocene of Gisborne district). Similar faunas have been obtained from the grey sandstones that overlie the phosphate-band in the Conway, near Ferniehurst.

The Bourne conglomerates and sandstones of Pliocene age unconformably overlie the Ihungian beds. They are highly folded in places and involved in major earth-movements.

Tilted Pleistocene gravels and interbedded silts crop out in the Kowhai river-bed, one mile south-west of Trig. K.A.

Younger Pleistocene and Recent gravels, sands, and silts form a veneer on extensive river-terraces, raised beaches, and river-flood plains.

Dr. Finlay's work on the Foraminifera shows that much of what in the coastal sections north of the Hurunui has been considered the equivalent of the Weka Pass stone, the Grey Marl and the Mount Brown beds is younger than any of these.

Igneous Rocks.—Basic dykes, probably contemporaneous with the mid-Tertiary volcanicity that resulted in the effusion of the Cookson volcanic rocks, intersect the greywackes. At Corner Hill an amygdaloidal basalt, probably of the same age, is involved in the overthrust faulting.

Economic Geology.

Coal.—Traces of coal or coaly substances occur at several places in the subdivision, but nowhere has any outcrop been seen that warrants any systematic search for payable seams, which appear to be entirely absent.

Oil.—The Cretaceous and Tertiary rocks contain oil at several localities in New Zealand, and, by some, rocks of this age have been regarded as a possible source of oil within the Kaikoura Subdivision. In this area, however, there is a complete absence of most of the structural conditions essential for a productive field.

Gas.—Natural gas (Marsh gas) is reported in considerable quantities at shallow depths in a bore in the Kaikoura Plains. This gas may be present in quantities sufficient for domestic purposes and for generating power for milking-plants. Records of the quantity of any gas encountered in well-sinking in this area should be systematically kept.

Limestone.—At many localities where the Amuri limestone crops out a suitable agricultural lime can be obtained.

Asbestos.—A small specimen of slip-fibre asbestos is reported as having been obtained from the highlands in the south-east of the Greenburn Survey District.

Gold.—A concentrate of magnetite, garnet, and zircon, with a little fine gold, was obtained by Mr. Leaman from a beach lead at the mouth of Medina Creek, Hawkswood Survey District. When the locality was visited no beach lead was visible, but a barren concentrate with the same minerals as those of the concentrate that contained the gold was washed from the beach-sands. This beach gold was probably derived after several reconcentrations by the streams and the sea from the conglomerate cropping out among the greywacke rocks, and consisting mainly of igneous rocks, many of which must have come from an area west of the present main divide. A few dishes panned from the debris from an outcrop of this conglomerate by the bridge over the Hurunui, two miles upstream from Ethelton, yielded three extremely fine specks of gold.

Neither the beach-sands not the conglomerate is regarded as a possible economic source of gold.

Building-stone.—A quarry, recently opened in the Tertiary tuffaceous limestone at Marble Point, ten miles from Hanmer, yields a "marble" of light pinkish-brown to brownish-red shades that takes a high polish. The stone, which is the Cookson limestone of earlier reports, is suitable for interior decorations and has been so used in some recent buildings.

Manganese.—At Hanmer there is a small patch of manganese oxide about 60 chains north-west of Trig. H. The oxide contains siliceous and iron impurities, outcrops for a chain in length, and is only a few feet in width, so there is extremely little possibility of the occurrence being of commercial value.

PALÆONTOLOGICAL REPORT.

(By J. Marwick.)

During the past year routine work of identifying, cataloguing, and building up the collection of fossil and recent mollusca, and of attending to correspondence, has occupied considerable time. The geological description of Wharekuri Basin was written up and a start made on a comparison of the Molluscan faunas of Wharekuri, Otiake, and Awamoa. This, it is hoped, will throw additional light on the correlations of the marine Tertiary strata of Central Otago and Southland. Molluscan faunules

from a number of places in these districts—*e.g.*, Kyeburn, Naseby, Lake Wakatipu, and Wakaia—have been examined; and their study, though far from completed, shows that the marine transgression which caused their deposition, though of wide extent, was of comparatively short duration and ended earlier in the Tertiary than has generally been supposed. The Kyeburn fossiliferous beds appear to be somewhat younger than the Wakaia and Chatton ones and may be equivalent to some of the Clifden zones. All the faunas from the beds mentioned belong to the period between the Waimatean and the Awamoan and can be conveniently regarded as of Oligocene age.

Although we cannot as yet correlate with the European time-scale in any exact way, the relative stratigraphical position, as well as the great differences shown by the contained mollusca compared with those of Recent seas, indicate that the Awamoan is at least as old as Lower Miocene. Consequently, the greater part of Otago and Southland must have emerged from the sea about the end of the Oligocene period, and has been exposed to subaerial denudation throughout the Miocene, Pliocene, Pleistocene, and Recent. This has a bearing on the theory recently advanced by W. N. Benson (H. Service, 1934, N.Z. Jour. Sci. & Tech., Vol. 15, pp. 263–79; Benson, Bartrum, and King, 1934, T.R.S.N.Z., Vol. 64, pp. 54–59) of pre-Kaikoura peneplanation.

For several months past, Dr. H. J. Finlay, through the medium of the Unemployment Board, has been employed in a study of Cretaceous and Tertiary Foraminifera. Although foraminiferal studies offer the best means of attack on many of our stratigraphical problems, this department of palæontology has hitherto been sadly neglected in New Zealand.

Through the agency of Mr. E. O. Macpherson, a small but interesting collection of Lower Jurassic fossils was forwarded by Miss P. Sandys Wünsch, of Wyndham. These fossils were collected from a rapid in the Wyndham River, half a mile east of Glenham Road, Wyndham Survey District, and consist of *Chlamys* n. sp., *Pseudaucella marshalli* (Trech.), *Pleurotomaria* n. sp., and *Rhynchonella* sp. The *Pseudaucella* is a zone fossil for the Lower Jurassic of New Zealand, and this is the first known record of its occurring along with other fossils.

Several ammonites have recently been added to the Geological Survey collections from different localities, and last year Professor W. N. Benson kindly arranged to have these and sundry other specimens examined at the British Museum. We are much indebted to Dr. F. Spath, of the Museum staff, for supplying the following identifications:—

Species.	Locality.	Collector.	Age.
* Macrocephalitid (*Kamptokephalites ?*) * cf. Sula Islands forms of G. Böhm	Scotchman's Bonnet Quarry, Owaka	P. Marshall ..	Callovian ?
† *Streblites* cf. *indopictus* Uhlig ..	Te Puti Point, Kawhia	J. A. Bartrum ..	..
‡ *Lytoceras* sp. large spec.	North end Waikiekie Peninsula, Kawhia Harbour	L. C. King ..	..
‡ *Lytoceras* sp. frag.	East side, Waikickie Peninsula, Kawhia	,, ..	Tithonian.
‡ *Kossmatia* sp. nov. 1 (Transition to *Paraboliceras*)	East side, Waikiekie Peninsula ..	,, ..	,,
‡ *Kossmatia* sp. nov. 2	,, ..	,, ..	,,
‡ *Berriasella* sp. juv.	,, ..	,, ..	,,
‡ *Aspidoceras* sp. (aff. *andinum*) and *cieneguitense* Steuer	,, ..	,, ..	,,
* *Gaudryceras* sp...	Waipawa Series, Section 85, Block 4, Motuotaria Survey District	E. O. Macpherson	Senonian.
* *Diplomoceras* sp. cf. *cylindraceum* Defr.	Waipawa Series, Section 41, Block 4, Motuotaria Survey District	,,	Upper Senonian.
* *Parapuzosia* aff. *haughtoni* Spath..	Bushgrove Creek, Mangapakeha Survey District	M. Ongley ..	Senonian.

* Specimen at New Zealand Geological Survey. † Specimen at Auckland University College. ‡ Specimen at Victoria College, Wellington.

NOTES ON THE GEOLOGY OF THE MARLBOROUGH GOLDFIELDS.

(By J. Henderson.)

The writer spent from 29th October to 4th November, 1934, at Top Valley, and, with Captain H. E. Humphreys, who owns the claim, examined as far as was possible the partly collapsed workings of the old Jubilee Mine. This mine was actively prospected during the early years of the century and yielded gold to the value of £4,183 from 3,673 tons of ore. It paid no dividends, but the increased price of gold makes the property interesting as a possibly profitable source of that metal. On other occasions the writer has visited Wakamarina, Havelock, and Mahakipawa.

Physiography.

Top Valley is drained by a considerable stream which enters the Wairau from the north about twenty-eight miles west from Blenheim, the principal centre of the Wairau lowlands. These lowlands near the sea are ten miles to twelve miles wide and are bounded north and south by highlands which converge westward, so that forty miles from Cloudy Bay they are represented practically by the shingle-bed, stony flood-plain, and young terraces of the Wairau. Thick deposits of late Tertiary gravels, carved into downs and hill groups, extend almost continuously along the southern part of the low country, and toward the western end constitute nearly the whole. Flats, built by the Wairau and its branches from the south, cover most of the eastern part and form the rich arable lands of the Wairau Plain.

On both sides of the lowland toward the east and on the north side toward the west the landscape is distinguished by an immediate contrast between mountains and plain. On the south the highlands are the northern part of the great elevated mass of greywacke that occupies most of southern Marlborough. On the north a similar smaller and less-elevated highland mass extends west to the Nelson lowlands and north to Cook Strait. Both groups of highlands rise abruptly, the slope on the south side being a faulted down-warp (*fide* L. C. King) and that on the north a denuded fault-scarp. McKay (22 ; p. 19), who first suggested that an earth-fracture separated the mountains north of the Wairau depression, does not adequately describe the " Wairau Fault " and presumably relied on the strong physiographic evidence of its presence. Cotton (3 ; p. 321) mentions the fault, and Branch and Dagger (2 ; p. 124) have lately shown that Recent movement has occurred along it. For twenty miles the road to Top Valley follows a nearly straight scarp (probably a fault-line scarp), the line of which may obviously be extended across the wide flaring valleys of the several short streams from the highlands. The frontal slopes are everywhere steep, rising usually 700 ft. to 800 ft. in half a mile ; for long distances they are precipitous to a height of 200 ft. or more, probably modified by the lateral cutting of the Wairau, which flows close to the northern edge of the depression. The geological evidence of faulting is poor—no crush zone or outcrop of crushed rock is known along or near the highland edge.

As stated above, the Wairau flows along the foot of the northern highlands. The upper Wairau and the tributaries the main stream receives from the south—Branch, Waihopai, and Omaka—extend into the southern highlands twelve to twenty miles from the depression ; on the other hand, the long straight divide to the north is but six or seven miles from it. Within the basin of the Wairau the southern mountains average about a thousand feet higher than the northern. Again, the southern highlands are treeless, whereas the northern are still for the most part densely forested. These factors explain why gravel derived from the greywacke highlands to the south greatly predominates over that from the schist mountains to the north and why the Wairau, a greatly overloaded and strongly aggrading stream, has been forced over to the northern boundary of the depression.

Each tributary from the north as it enters the plain is diverted east by the steadily accumulating Wairau gravels. Timms and Onamulutu Streams each flow parallel with the Wairau for over two miles before crossing the low, separating flat of gravel and silt. Bartlett Creek suffers the least diversion, for, close east of its valley-mouth, the Wairau impinges against the schist bluffs of the highlands.

Where the Onamulutu reaches the plain (two miles above its junction with Wairau) schist-outliers project through the gravels. A prospecting-shaft in this locality penetrated 30 ft. of greywacke gravel, overlying 26 ft. of schist gravel, probably from the Onamulutu basin, before bottoming on schist. Here the Wairau has raised its bed and the plain at least 30 ft.

Decided infilling has occurred in the lower Onamulutu, where the goldfields Warden for several years reported that a deep lead was being worked. The floor of the lower six miles of Top Valley is being aggraded. For 30 chains upstream from the Wairau Plain there is a 20 ft. terrace on the west side of the valley, but elsewhere the stream swings from side to side of the valley in a wide, braided channel which is but a few feet below the flood-plain occupying the rest of the floor. Four miles upstream the floor is 15 chains wide, and from it schist slopes rise about 1 in 3 for a thousand feet or more. Obviously there is a topographic discordance and an immature highland valley is being infilled.

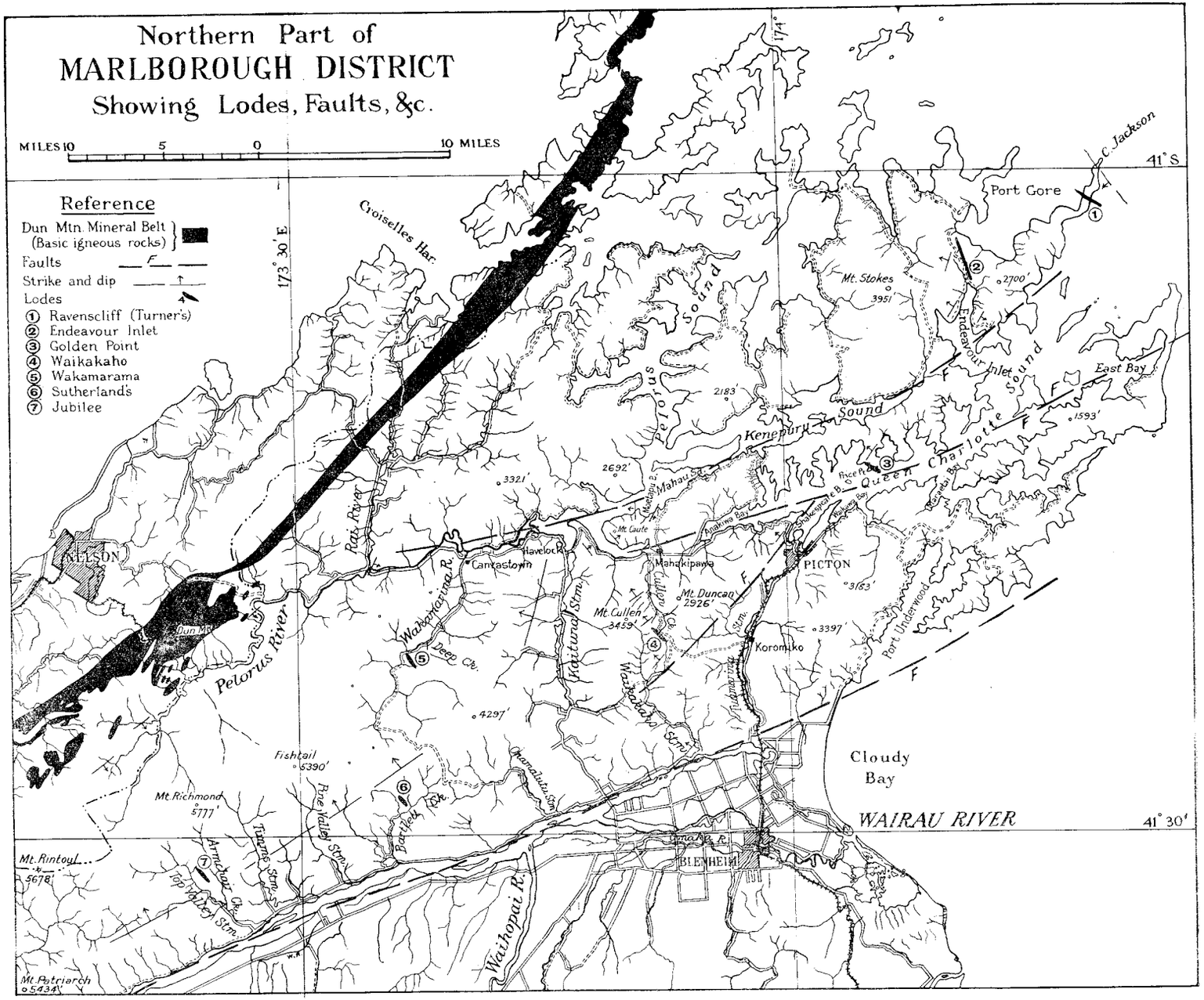
The other tributaries of the Wairau from the north for twenty miles east of Top Valley have not been examined, but as far as can be seen from the road their lower valleys resemble that of Top Valley Stream.

The Blenheim–Nelson road follows a narrow valley extending north and south through the schist highlands from the Wairau Plain to the head of Pelorus Sound. The Kaituna drains the northern eight miles of this valley to the sound which it enters at Havelock. The southern five miles seems to discharge to the Wairau ; but this section of the valley has a very gentle slope, rising from 160 ft. where it joins the plain to 210 ft. where the road crosses from the west to the east side just south of where the Okuramio, a considerable source of the Kaituna, enters from the east. The road up to this point skirts the west side of the valley to avoid the swampy centre. A prospecting-shaft in this valley, four miles and a half from the plain, is reported to have penetrated " Wairau " gravels.

The Waikakaho joins the Wairau five miles farther east. This stream, which has not been visited, rises on Mount Cullen (3,459 ft.), a peak about eight miles from where it enters the Wairau. McKay (20 ; p. 43) states that the descent to the Waikakaho from the saddle at the head of Cullen Creek, which flows north to Mahakipawa Arm of Pelorus Sound, is very abrupt, and Mr. Warden Allen (C.–2, 1889, p. 107) reports that flats extend six or seven miles up the Waikakaho and that up or near the upper end prospecting-shafts penetrated up to 90 ft. of gravel before reaching bed-rock. Probably in this valley, as in the others farther west, there is the same contrast of steep slopes rising sharply from disproportionately extensive flats.

Cotton (3) has shown that the Tuamarina, the next small northern branch of the Wairau, which it enters ten miles east from the valley followed by the Blenheim–Nelson road, has been dammed by the advancing deposits of the Wairau and has had its lower valley converted into a swamp. In six miles from Tuamarina, on the edge of the Wairau Plain, to Koromiko, near the head of the swamp, the valley-floor rises from 20 ft. to 60 ft. above sea-level (compare with rise along swampy south end of the Kaituna Valley).

Thus for thirty miles the tributaries of the Wairau from the northern highlands all show in their lower valleys physiographic effects due to the building-up of the Wairau Plain. At the same time the river-deposits have been pushed forward into Cloudy Bay, so that, as Cotton (3 ; pp. 320–21) points out, the plain now extends several miles farther seaward than it did within comparatively recent times.



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McKay (18 ; p. 100) suggested fifty years ago that the highlands north of the Wairau depression had been carved from a mass uplifted with a surface of low relief, or as he, following the ideas current at the time, puts it, "a plain of marine denudation, highest along its south and south-east boundary, and sloping gently to the north. This is shown by the fact that all the rivers traversing [these highlands] rise close to the south-east boundary, and within a short distance of the Wairau Valley, the slope on the south-east side from the height of land into the Wairau Valley being very abrupt. The same thing is shown in Mount Rintoul, the flat top of which is the only remaining portion of this now denuded plateau, from which all the mountains have been sculptured by sub-aerial denudation." Presumably the elevation and tilting here mentioned occurred in the late Tertiary, when the faults bounding the Wairau depression were formed and the mountains of New Zealand uplifted.

Within late geological times parts, and probably the whole, of the area have suffered both depression and elevation. The sounds are obviously river-valleys invaded by the sea owing to land-subsidence. Cotton (3 ; p. 318) prefers, in the absence of contrary evidence, to consider that the Sounds valleys were formed during a single erosion cycle, the alluvial deposits on which Picton is built being regarded as the unsubmerged and wave-reduced remnant of the flood-plain of the Queen Charlotte Stream. The remnants of marine deposits of approximately similar height, 30 ft. to 40 ft., present at several widely separated localities in the upper reaches of the Pelorus Sound (as at Havelock, along the south shore of Mahakipawa Arm, and on the west side of Moetapu Bay) can, however, hardly be regarded as the parts of a large flood-plain that have survived wave-attack. There can be no doubt that the area about the upper end of Pelorus Sound, and probably a much larger area, has been subject to Recent uplift of the order of 40 ft. Such an uplift would explain the presence of the low terraces near Cullenville and along the Wakamarina, in both localities worked for gold, and also the entrenching of the Pelorus River between the Wakamarina and Rai junctions. (At Rai junction the river is entrenched 30 ft. in a flat 70 ft. above sea-level.) McKay (20 ; p. 40) remarks that Cullen Creek "has been enabled to cut down the first-formed gravels, which without an elevation of the land [40 ft.] could not well be accomplished as here the grade could not be increased by a shortening of the course of the stream by erosion of the coast-line." The 20 ft. to 30 ft. terraces of unweathered gravel in the lower parts of all the branches of the Wairau between Top Valley and Bartlett Creek may be ascribed to uplift, the evidence for which the building-up of the Wairau Plain has not yet obliterated.

The flats of the lower Rai drop is six miles from about 170 ft. above the sea to 120 ft. close to the junction with the Pelorus. Four and a half miles downstream from this junction and about a mile west of the Wakamarina Bridge the Nelson–Blenheim road leaves lower flats and crosses a terrace 95 ft. above the adjacent tidal river. This terrace is interpreted as a remnant of the former continuation of the Rai Flat.

McKay (20, pp. 41–2) noted that much-weathered stream deposits were being worked for gold on the west side of Cullen Creek some 300 ft. above present stream-level. Near the head of the valley there are well-marked terraces at heights of 800 ft. and (?) 1,200 ft. above the sea and several hundred feet above the narrow ravine in which Cullen Creek flows. These terraces are but three and a half miles from the shore of Mahakipawa Arm and less than two miles from the head (120 ft.) of the flats extending along the lower valley of the stream. The conclusion that the sea once stood 500 ft. or more higher than now can hardly be resisted.

There are high-terrace remnants in Top Valley. Bell's Terrace, half a mile below the junction of Armchair Creek, consists of coarse, weathered gravel the top of which is 120 ft. above stream-level. Eve's Terrace, nearly opposite on the east side of the valley, is similar. Decomposed gravel, the "old man wash" of the digger, is reported to occur at many points and at different heights in the Wairau tributaries east from Top Valley, but Bell's Terrace was the only outcrop actually examined. Several others, showing no clear topographic evidence of their presence and probably consisting of small masses of gravel clinging to hill-sides, were pointed out in Top Valley and along the steep slopes facing the Wairau between Bartlett and Onamulutu Streams.

The fragmental evidence detailed above, which closer study will probably greatly increase and extend over wider districts, shows clearly that the block was formerly much lower than it now is and that its post-Tertiary history is complex.

Geology.

Hector (11 ; pp. 119–20) subdivides the metamorphic rocks of the highlands north of the Wairau depression in downward order as follows: (*a*) Quartzite and quartz schist; (*b*) blue slates; and (*c*) feldspathic and micaceous schists. The blue slates, which would in modern nomeclature be described rather as phyllites, and the feldspathic schists together constitute McKay's (20 ; pp. 36–7 and 21 ; pp. 103–11) lower group of schists, the other subdivision being his upper, less-altered group. This younger group contains a considerable proportion of quartzose schist and quartzite and grades upward through subschists into greywackes and fine breccias. Thick bands of quartzite and quartz schist, according to McKay (18 ; pp. 103–4), form the main range extending from Mount Richmond east to the head of Bartlett Creek and thence nearly north to Havelock. The impressive bare, stepped precipices of Mount Richmond (5,777 ft.), rising from steep, wooded slopes, seem from a distant aspect to have been carved from thick massive layers of hard rock dipping gently northward.

The writer has not seen the "finely laminated blue slates" of Bartlett Creek, and McKay (18 ; p. 103) did not observe them south-west of the basin of that stream, but their tendency to "weather on a surface of steep spurs to red and pale-fawn coloured splinters" (11 ; p. 120) recalls the weathering of the phyllites occupying the same relative position in the rock-sequence in Top Valley. Here phyllites, dipping north-west toward Mount Richmond, form Jubilee Ridge for about a mile downstream from the "forks" of Top Valley ; how far they extend farther along the streams draining from the main

range is not known. Jubilee Ridge, a spur from the highlands, crosses the schistosity-planes nearly at right angles, and where formed of phyllites is about 900 ft. above the floor of Top Valley. Southward the ridge, though narrower, is from 300 ft. to 600 ft. higher over a length of about two miles, being formed of more resistant rocks, which are thought to be the upper part of Hector's feldspathic schists.

The schistose greywackes near the junction of Deep Creek with the Wakamarina probably closely overlie the quartzose schists of the main range. These latter, dipping gently north from the crest of the main range, are, according to McKay (21 ; p. 110), cut by the profound ravine or chasm of Deep Creek. The greywackes are massive and rather coarse and not so altered but that their original texture and structure can generally be made out. Nothing further can be added to McKay's account of these rocks, which constitute the Te Anau Series (21 ; pp. 111–5) and which grade upward into non-schistose rocks.

Near Deep Creek the schistosity-planes and bedding-planes are undoubtedly parallel, and the same concordance is obvious west of Havelock and about Mahakipawa, where phyllites and quartzose schists are interbedded. In Top Valley green feldspathic schists, quartz-schists and phyllites, wherever observed, were parallel. On the north end of Jubilee Ridge the writer found a loose fragment of phyllite in which the schistosity definitely crossed the bedding. Nevertheless, from the available evidence, it seems a reasonable conclusion that the planes of original deposition of the rocks and schistosity-planes are, in general, concordant throughout the district.

The thickness of the schistose rocks is very great. From Mount Richmond to the Wairau is seven miles, the dips in the lower four miles and a half of the valley ranging from 20° to 50° and averaging, say, 30° ; for the remainder of the section the dips are flatter, say, 15°. Faulting seems to have caused no important repetition of the strata, the thickness of which can hardly be less than 20,000 ft. and may well be 25,000 ft. or even more.

Dr. Turner, of Otago University, very kindly sectioned and examined a few rocks from Top Valley. He found that they agreed very closely with the less-metamorphosed members of the Otago schists and that all the rocks could be matched exactly in texture and mineral-composition with schists from Otago. In this he agrees with every geologist, from Hector (11 ; p. 119) onward, who has examined both regions.

Three rocks were analysed in the Dominion Laboratory. The first, from the upper audit of the Just-for-Luck Claim, probably belongs to the lower part of Hector's " Blue Slate " group. Dr. Turner describes it as a slightly foliated sericite-chlorite-schist containing about 80 per cent. of sericite, 15 per cent. of pale-green chlorite, and 2 per cent. or 3 per cent. of quartz, together with accessory iron ore and epidote. The second rock, from the Sylvia adit, is about 1,200 ft. lower in the sequence. Dr. Turner decribes it as a non-foliated, highly fissile green schist containing quartz, pale clinozoisite, epidote, sericite, and pale-green chlorite. The third, collected at Picton by Mr. L. C. King, has not been sectioned. Analyses 4 and 5 of the table are of sub-schistose rocks from Wakamarima (15 ; p. 13).

	(1)	(2)	(3)	(4)	(5)
SiO_2	51·08	54·59	61·59	62·97	68·93
Al_2O_3	22·82	16·52	17·07	14·37	12·66
Fe_2O_3	1·24	2·00	3·06	2·24	1·64
FeO	6·92	7·19	3·21	4·68	3·67
MgO	2·86	3·86	1·87	2·14	1·62
CaO	1·56	5·94	2·39	3·75	2·44
Na_2O	2·32	2·60	3·73	3·98	3·47
K_2O	3·68	1·58	2·15	2·24	1·78
Water lost below 105° C.	0·60	0·22	0·46	0·14	0·10
Water lost above 105° C.	4·96	4·60	3·03	2·87	3·14
TiO_2	0·99	0·65	0·76	0·64	0·45
P_2O_5	0·51	0·22	0·25	..	..
S	0·01	0·01	Trace	..	..
MnO	0·14	0·13	0·13	..	..
Cr_2O_3	0·02	0·03	None	..	..
BaO	0·08	0·03	0·05	..	..
CO_2	None	Trace (?)	Trace	..	..
	99·79	100·17	99·75	100·02	99·90

(1) Sericite-chlorite-schist, Upper adit, Just-for-Luck, Top Valley.
(2) Epidote-quartz-schist, Sylvia adit, Top Valley.
(3) Schist, Picton. Contains also a trace of free carbon. Collected by L. C. King.
(4) Schistose greywacke, No. 4 adit, Empire City Claim, Wakamarina.
(5) Schistose greywacke, No. 3 adit, Empire City Claim, Wakamarina.

Excluding the first, the rocks analysed contain more lime than magnesia and more soda than potash, facts indicating that the sediments were composed of unleached particles, possibly largely consisting of tuff or of unweathered fragments from areas of igneous rock.

The concordance of the original bedding-planes and the schistosity-planes suggests that the metamorphism developed horizontally and that the pressures involved were vertical. The rocks are thick and the gradation from one stage of metamorphism to another is unperceptible in the field, so that alteration brought about by a large igneous mass is improbable. Static metamorphism caused by intense vertical pressure following on deep burial, combined with the increased temperatures of depth, and aided by solutions trapped in the original sediments seems to be the only process of recrystallization that fits all the facts.

The physiographic structure of the area is discussed in the next section. The great faults and the crushed and steeply dipping schists adjoining them, as well as the broad open folds in the large areas between the faults, are obviously younger than the metamorphism. Indeed, the schists as a whole are no more disturbed than most areas of Tertiary strata of equal size, a fact suggesting that their deformation was due to stresses active during late Tertiary time. The relation to the schists of the sharply folded late Palæozoic and early Mesozoic strata of the highlands adjoining on the north-west is not definitely known. Probably the stresses that culminated in the orogeny of the early Cretaceous folded these rocks, while still weak and unconsolidated, against the resistant, already schistose, mass, which itself suffered little deformation. On this hypothesis, the Marlborough schist must be at least of pre-Carboniferous age. Since a great series of non-schistose rocks usually referred to the Devonian underlie the Matai (Carboniferous) rocks of Nelson, and since no Silurian rocks are known in New Zealand, the Marlborough schists are probably pre-Silurian. They differ from the dynamically altered Ordovician schists of western Nelson in that they contain a good deal of volcanic material, but no strongly calcareous layers and no graptolite-bearing black bands. At present it seems best to regard the Marlborough schists as of Archaean age.

Structure.

Observations in Top Valley and along the road between Onamulutu and Top Valley agree with McKay's (21 ; p. 104) generalization that the schistosity planes have a regional north-west dip. Except near faults the dips of the rocks of Jubilee Ridge are consistently to the north-west at from 25° to 50°. As the schistosity decidedly influences the details of surface-form it can be confidently stated that the rocks immediately west of Top Valley also dip north-west. Hector (11 ; p. 120) describes the dips in the basin of Bartlett Creek as ranging between 50° and 70° toward the north-west and west. At Havelock and along the west side of the Kaituna Valley for at least four miles south of the town the schists strike a few degrees east of north and dip west at from 30° to 50°. These observations, combined with what is known of the distribution of the thick quartzose schists higher in the sequence, suggest that the whole schist area west of the Kaituna forms the end on an open syncline pitching north-west, the east-north-east-striking limb passing through the highlands for twenty miles east from Top Valley and the north-striking limb through the highlands west from the Kaituna. In the trough of the syncline along the Wakamarina McKay (18 ; p. 104) reports low irregular dips.

The gently curved Kaituna Valley, that provides so easy a route through the fifteen miles of highland rising abruptly on either side of the narrow opening, is decidedly anomalous and suggests a structural break of some sort ; it may have been excavated along a fault or a fold sharp enough to weaken the schist. There is some indication that the valley, in parts at least, marks a change in structure. South from Havelock, on the west side of the valley, the schists dip west, whereas on the east side of the ridge between Kaituna and Mahakipawa Arms of Pelorus Sound they form extensive dip-slopes declined north-east. This north-east dip is maintained along the north-east shore of Mahakipawa Arm, but the strikes and dips of the mass of the peninsula between this inlet and Moetapu Bay are irregular. Farther south for three miles along upper Cullen Creek the schistosity planes strike east-north-east and dip west-north-west at from 30° to 80°. Still farther south along the Waikakaho McKay (20 ; p. 43) reports changes in strike and dip and, along the banks of the Wairau, a north-west dip.

Probably the changes in strike and dip in the Waikakaho are connected with the Picton fracture-zone. Morgan (25 ; pp. 15–6) gives the best description of this fault, which McKay (17 ; pp. 92–3) suggested continued along the main part of Queen Charlotte Sound and East Bay separating the schists of the north-west shore of the inlet from the sandstones and greywackes of the south-east side. The Queen Charlotte Fault is parallel with the Wairau Fault and offsets it about ten miles ; probably it continues with lessening intensity along the head of the sound into Mahakipawa Arm, the Picton fracture-zone being regarded as a link between the Wairau and Queen Charlotte faults.

Other valleys and inlets extended along a line parallel to the Queen Charlotte fault, and about four miles north of it are the lower Pelorus Valley, the head of Pelorus Sound, Mahau Sound, and the chief part of Kenepuru Sound. McKay (21 ; see map, p. 96) separates his " foliated schists " from his higher less-metamorphosed " Kakanui Series " along this line, which probably marks a strong fault. Farther west " the relation of the Te Anau Series " [the next higher group of beds] " to the higher part of the Kakanui Series is very peculiar. Throughout the whole of the eastern part of the Pelorus Valley the dip of the breccias, sandstones, and slates composing the Te Anau Series is to the south-east and south, and at all places examined they appear to pass under the more altered and presumably older rocks ; and this seems to be the mode of junction along the whole length of their southern boundary . . . The junction is therefore in all probability a line of fault " (21 ; p. 115).

The Endeavour Inlet antimony lode seems to be a fault traceable for several miles north-north-west from Resolution Bay. Westward Mount Stokes (3,951 ft.), the highest point of the considerable area between Endeavour Inlet and Pelorus Sound, consists of sub-schists lying nearly flat (19 ; p. 11 and 21 ; p. 109).

The map shows the dips and strikes of the schistosity planes so far as recorded at a few other localities.

Alluvial Gold.

Shortly after Marlborough was separated from Nelson (late in 1859) the Provincial Council offered a substantial bonus for the discovery of a payable goldfield. The wife of a sawmiller, at what was later known as Canvastown, seems to have first (in 1860) found alluvial gold. This was in the bed of the Wakamarina, where, early in April, 1864, after several abortive attempts by others, a highly profitable diggings was discovered by Messrs. Rutland (two), Harris, and Wilson. The easily-worked ground was soon exhausted; in 1865 the output was only a third of that of 1864, and many miners left for the newly-found West Coast diggings. Nevertheless, the Wakamarina, in the Pelorous Mining District, was the most important diggings in Marlborough and maintained a small population for many years.

As early as 1860 odd colours had been found in the northern tributaries of the Wairau, and in 1865 miners from the Wakamarina prospected the Onamulutu and Bartlett Valleys with but indifferent results. Timms and Bartlett, whose names are commemorated in the streams they worked, Cawte, the discoverer of gold near Langley Dale, and Cooper, who got gold in Cockatoo Creek, were more successful, but the several diggings of what was termed the "Wairau Mining District" were, in general, short-lived (a few months only), and Hector (11; p. 121) in May, 1872, wrote of Bartlett Valley: "Although I was informed that within the last two years about two hundered to three hundred men have been at work in the district, yet the claims are now altogether abandoned"; and of the Onamulutu (11; p. 123): "These diggings were all in full working during 1869–70, but only a few men are still at work in that neighbourhood." The early Wardens (1873–79) generally refer to the Wairau field as almost deserted, most of the few miners being in the Onamulutu Valley. McKay (18, p. 103) visited the district about Christmas, 1878, and observed gold-workings then deserted as far up the Wairau Valley as Top Valley, but not beyond. Mr. Warden Allen (H.–26, 1880, p. 12) writes, "Payable gold, however, was found in the late autumn of 1880 in Armchair Creek, but better returns were obtained from the flats and small branches of Top Valley. This ground cannot fairly be styled a new diggings. It is a fact that has been well known for many years that gold could be found in the different creeks and valleys on the north bank of the Wairau from Onamulutu Valley to Mount Patriarch." About this time the country west of Top Valley was prospected; Tipperary and Enchanted Creeks, Birch Hill and Lambert gullies, and other small valleys, all cut in the schist rocks, were worked. But the miners as a whole were not very successful, for water was scanty in the summer. The goldfields were a "convenience"; when shearing was over and nothing better offered, men would go digging.

The latest important discovery of alluvial gold in Marlborough was at Cullen Creek. Charles Jackson began prospecting there in January, 1888, and reported the discovery of alluvial gold in the upper valley in May. Two hundred men were on the ground in a few weeks, and gold was shortly after found in the Waikakaho, which heads to the source of Cullen Creek from the Wairau. Other streams draining the schist highlands east of the Kaituna Valley were also found to be auriferous—White Pine and Snow discharging into Mahakipawa Arm, Duncan and Ada Creeks flowing to Anakiwa Bay at the head of Queen Charlotte Sound, and Bragg and Koromiko Creeks, branches of the Taumarina.

After the quick exhaustion of the easily won gold of the beaches and bars of the larger streams and that on the bed-rock and in the crevices of the channels of the smaller, the miners turned their attention to the less-concentrated and less-readily worked deposits of the flood-plains and terraces and to the high-grade wash of deep leads. As already pointed out, terraces are not prominent in the district, far less prominent than on the West Coast and Otago goldfields. They are most extensive in the Wakamarina Valley, where low terraces have been worked on a considerable scale. In Cullen Creek the highly profitable terrace worked by Carr and Davis seems to be a rock-defended part of the 30 ft. to 40 ft. terrace that extends along the lower valley. Terrace-remnants at higher levels also occur and have been worked where water was available. Of the gold-bearing branches of the Wairau, Top Valley contained two inextensive terraces, and reports of the other valleys suggest remnants of weathered gravels clinging to hillsides rather than to topographically-distinct benches.

On the other hand, deep leads are important in the in-filled lower valleys of several of the streams. The bars and beaches of the Wakamarina were so exceptionally rich that great, or at least considerable, accumulations of gold were popularly expected at the bottoms of the gorges. As early as 1878 unsuccessful attempts were made to reach bottom by air-lock. Near Quayle Creek, at Wakamarina Gorge near Deep Creek, and at Maori Gorge near Dead Horse Creek, the river was diverted through excavated channels. It is doubtful if any of these schemes was commercially successful. Of the last mentioned, Mr. Warden Allen (C.–2, 1889, p. 106) writes, "It may be interesting to those who are inclined to speculate in cleaning out smooth rocky-bottom river claims to note briefly the proceedings of the Maori Gorge Co. They have employed, on the average, about twelve or thirteen men for nine months; they have removed from the bed of the river about 3,000 to 4,000 tons of gravel; they have expended upon machinery, and labour, and plant about £1,000, and they have found about 17 oz. of gold. The only satisfactory result to the company may possibly be that they have gained a great amount of experience." Several attempts were also made to "drive out" the wash of a deep lead in the Wakamarina, and the Warden (*ibid.*) records a shaft 80 ft. deep near Maori Gorge.

Beyond the fact that the deep lead worked in the Onamulutu Valley during the "seventies" was very wet, no information is available of this deposit. In 1903 the Inspector of Mines (C.–3, 1903, p. 103) reports that deep, wet ground was being worked in Bartlett Creek. So far the deep lead at the head of the Cullen Creek flat has been the most profitable. This yielded good returns in the "nineties," but later, as depth increased, water gave constant trouble and work was slow and intermittent. A few years ago the Mahakipawa Co. sank a shaft more than half a mile from the head of the flat and installed large electrically-driven pumps; at present this is the largest mining enterprise in Marlborough.

The history of dredging in Marlborough is brief and inglorious. The Pelorous estuary, the shallow head of Mahakipawa Arm, the flats of the Wakamarina up to the Gorge, as well as the flats of Top and Pine Valleys and of the other branches of the Wairau, were pegged out and some boring was done. The Wakamarina dredge was at work in 1898, but its ladder was too short to reach the bed-rock near the Gorge. In the Wakamarina the Golden Point dredge worked for two years or more, but the Imperial (near Quayle Creek) and the Moana closed down shortly after starting. In Top Valley the Omdurman (near Bell's Terrace) and the Pride of Marlborough (near the forks) worked for very short periods. The only other mention of dredging in Marlborough in the Mines reports and Mines record is that a small prospecting-dredge worked on Mahakipawa Arm during part of 1899.

Lode-mining.

Rough gold to which quartz adheres is found in all the Marlborough diggings, and this early induced the miners to prospect for "reefs." The first to be worked was in the Bartlett Valley and is known as Sutherland's. The records available are incomplete; when it was first prospected and when the company was formed are not known. But by July, 1871, two adits had been driven, a battery erected, and tailings and concentrates from an unsatisfactory crushing examined in the Colonial Laboratory. Dr. Hector visited Sutherland's Mine, and on the map accompanying his report, which is dated 12th May, 1872, shows a reef, called the Golden Crown, on the west side of the Lower Onamulutu Valley and another as reported to outcrop in the Wakamarina Valley west of Deep Creek. Dr. Hector also visited Turner's Reef (found in 1870) on the narrow ridge that terminates in Cape Jackson, between the entrance of Queen Charlotte Sound and Port Gore.

Mr. Warden Whitehorn, reporting for the year ended 31st March, 1873, noted that "the Turner Gold-mining Co. (Registered)" was erecting crushing-machinery, that a reef had been found on Queen Charlotte Sound (probably the Golden Point, see below), and that three applications for leases on a "line of reef" in the Pelorus district (probably near Deep Creek) had been lodged. Next year he reported that the battery (ten-head) at Cape Jackson was erected and that a small amount of ore had been crushed for "a moderately satisfactory result." Prospecting continued in the Pelorus district and antimony ore of good quality was found in large amount at Endeavour Inlet, in which locality a lode of quartz and stibnite was known to be present at least as early as 1872 (11; p. 129).

Bartlett Creek.—Hector's report (11; pp. 119–25) contains the only information available about Sutherland's reef, and as this report has been out of print for many years the following abstract is given: The lode outcrops on the narrow ridge between Quartz and Criterion Creeks (and about 60 chains from the mouth of the former). The creeks are from 40 to 60 chains apart, and the steep interfluvial spur running nearly due north consists of blue slates (phyllites), which strike N. 55° E. and dip north-west. The lode, striking N. 40° W. and dipping 80° north-east, crosses the spur obliquely at a point where the ridge is 900 ft. above Bartlett Creek. A winze was sunk on the outcrop, and there are two adits—that on the east side of the spur being 130 ft. below the outcrop, and that on the west side 230 ft. A tram, 22 chains in length, connected the mouth of the lower adit with the battery in Quartz Creek 600 ft. below. When visited by Dr. Hector the mine was deserted, and he examined the vein as exposed at the outcrop and in the lower adit, where a clear body of white sugary quartz from 1 ft. to 2 ft. thick was visible. The lode and country contained no pyrites. A ton of ore from the upper adit crushed at Collingwood was found to contain 1 oz. 5 gr. of gold, and another crushing of 4 tons yielded at the rate of 12 dwt. per ton. From the lower adit 4 tons gave 1 dwt. per ton, and a crushing of 80 tons at the company's mill only 1 grain per ton. The Colonial Analyst examined tailings and blanketings from this last crushing and found them to contain respectively 2 dwt. and 13 dwt. per ton (Dr. Hector reduces these to 1 dwt. and 10 dwt. of pure gold). The poor results from the ore crushed in the company's mill are ascribed to the flouring and loss of mercury and to the severe frost during the crushing. These, combined with the inevitable losses occurring in a new plant owing to the tables not being exactly adjusted and to the plates being "raw," &c., sustain Hector's opinion that "it would be desirable that a proper trial of the mine should be made before it is abandoned." In 1879 the Warden (H.–26, 1880, p. 12) reports that a company, known as the "Picton and Havelock," had reopened the mine, had driven 270 ft., 215 ft. of crosscut and 50 ft. on lode, reported as 4 ft. wide, and had mined 120 tons of ore, the crushing of which did not prove satisfactory. Nothing further was found in the records except that in 1881 (H.–19, 1881, p. 19) the quartz claims in Bartlett Creek had been abandoned.

Ravenscliff District.—In 1875 the two companies working in the Cape Jackson area amalgamated. The Warden (H.–3, 1875, p. 8) reported that 700 oz. were obtained from 1,130 tons of ore, whereas the table with the report of the Secretary for the Goldfields shows 203 oz. from 370 tons. No further work was done for a few years, but in 1878 a London company, the Ravenscliff, acquired the leases, reopened the drives, and repaired the battery. During the next two years several small crushings were put through, with poor results. The Secretary for the Goldfields for the two years ended 31st March, 1881, reports that 920 tons yielded 295 oz. of gold; the annual report of the company for the year ended 30th June, 1880, shows 1,056 tons for 320 oz. In 1889 another attempt was made to work the claim, Mr. Warden Allen (C.–2, 1889, p. 106) reporting that the drives were cleaned out and 20 tons of ore brought to grass.

Dr. Hector's report (11; pp. 125–9) contains the only geological information available about the Cape Jackson area. Schists of different kinds form the narrow headland for several miles. The schistosity-planes strike steadily N. 40° W. and dip south-west at 50°. A reef zone crosses the narrow ridge rather more than two miles from Cape Jackson; in this locality the ridge is about 30 chains wide and 500 ft. high. The lode outcrops on the top of the ridge and is exposed in several open cuts for

400 ft. down the east side. A shaft, 20 ft. deep, sunk on the reef showed the vein to be from 15 in. to 30 in. thick, to strike N. 70° W. and to dip 75° southward. "The reef is composed of several distinct kinds of quartz differing in compactness and colour and divided by smooth joints parallel with the walls of the reef. There is no clay band or soft casing on either side of the reef, but the schists are soft and decomposed where they are in contact with the quartz" (11; pp. 126–7). Another shaft slightly over the brow on the west side of the ridge, cut the reef at 85 ft. from the surface. A crosscut from this shaft showed three veins of quartz, one of which was followed eastward for 30 ft. Down the west slope a quartz vein was traced for 1,000 ft. The quartz is similar to that on the east side of the ridge—the strike is the same, but the dip is in the opposite direction (70° N.); the reefs are probably the same. On the west side of the ridge, 80 ft. north of the reef, a strong quartz vein, 3 ft. to 4 ft. thick is exposed. Near the west end of the main lode a flat leader, traced for 4 ft. north, contained gold at the rate of 3 oz. to the ton.

According to the reports of the Wardens, 2,186 tons from this area yielded 1,020 oz., or 9·33 dwt. per ton. The reports of the Secretary of the Goldfields contain the following returns:—

Year.	Tons.	Oz. dwt. gr.	Reference.
1874	49	47 12 5	H.–9, p. 49.
1875	370	208 3 0	H.–3, p. 73.
1880	320	105 0 0	H.–26, p. 3.
1881	600	190 0 0	H.–17, p. 5.
	1,339	550 15 5	

The average per ton from these figures is 8·23 dwt.

Golden Point.—As early as 1873 auriferous quartz veins seem to have been known and prospected at Price Point, near the old Maori village at Kaipapa on the north side of Queen Charlotte Sound, and six miles north-east of Picton. Rich gold-bearing specimens were found in 1877, and prospecting continued for a number of years. Claims mentioned are the Golden Point and Kaipapa, and in 1881 these were merged in the Golden Eagle Co. In 1882 the Warden (H.–19, 1882, p. 18) reports that 20 tons of ore yielded 10 oz. of gold, and apparently the area was then abandoned.

Hector (12; pp. 1–5) gives the only published account of the area. The rocks are fine-grained, dark-grey mica schists containing thin laminæ of quartz. The foliation planes strike north-north-east and dip west at 40°. The rock is jointed, but there is little contortion of the foliation planes.

"Besides the thin laminæ, quartz occurs in veins or leaders that traverse the rock-mass in an irregular manner, expanding and contracting from a few inches to nearly 2 ft. in parts.

"At least six of these leaders are exposed within a distance of 60 ft. in the face of the sea cliff where the mine is situated, and about the same number has been met with in the underground working; but as far as yet followed they do not appear to form into a well-defined lode or reef.

"Cutting across these leaders and displacing them, vertical faults are seen in the sea cliff, and in the workings one of these is marked by a thin cross course or vein of banded quartz, carrying water. The direction of these faults is about N. 40° W. In the same line round the point on the beach . . . there is a wide vein of blue mullock or tenacious clay full of kernels of white quartz and minute crystals of pyrites. Further on, and still in the same line on the hill above, blocks of cherty iron-stone and quartz indicate the outcrop of a heavy reef . . .

"It is therefore probable, if a steady defined reef is found, it will have a north-west and south-east direction and easterly dip, and in this respect agree both with the Jackson and Sutherland reefs, and also with the auriferous quartz and antimony lode between Endeavour Inlet and Port Gore, so that north-west appears to be the prevailing course of mineral lodes in the district."

Hector took samples and made a number of tests, concluding that "some at least of the quartz-leaders contain a remunerative percentage of gold, provided that their extreme irregularity does not make mining too costly."

Hector does not give the strikes and dips of the individual leaders or of the leader-zone, if such indeed exists.

The workings, as they followed the leaders, seem to have been decidedly irregular. Hector mentions an adit above tide-level from the end of which a shaft 30 ft. deep was sunk. Mr. Warden Allen (H.–17, 1881, p. 19) reports that a main shaft had been sunk and that workings were 220 ft. below the surface of the ground. But the available information is altogether too scanty to allow one to picture their extent and general form.

Wakamarina District.—J. F. Downey (5; pp. 12–6) has summarized the history of lode mining in the Wakamarina district to the end of 1926. Since that date work continued intermittently in the Golden Bay – Empire City Mine till it ceased about the middle of 1930. This lode strikes north-west and dips steeply to the north-east. The rise in the price of gold has encouraged prospecting in the district, and, in addition to work on the lodes already known, gold-bearing quartz has been found at several points in the range separating the lower Pelorus from the Waikaihu Creek, a branch of the Kaituna.

Mahakipawa District.—In the Mahakipawa district, since Downey's excellent summary (5; pp. 7–10) appeared, a little prospecting has been done on the lodes near the saddle between Waikakaho and Cullen Creeks. The veins in this locality strike north-west and dip south-west. A strong lode of clean quartz has been found about three-quarters of a mile north-east of Mount Duncan (2,926 ft.). This lode is up to 8 ft. wide, strikes due north, dips east at about 75°, and has been traced 10 chains or more. A sample the writer took was barren, but, in view of the fact that

Duncan Creek carries alluvial gold, this lode deserves further attention. Near Moetapu Point, where detrital gold occurs in the beach-gravels, Mr. P. W. Soanes prospected an east-west zone of broken country containing irregular veinlets of gold-bearing quartz (14; pp. 21–2). Later he drove on a bedded vein or band of silicified quartz schist in the same locality. This, which strikes north and dips east at about 45°, shows pyrite freely. Though containing gold in small amount at the surface it seems to be nearly barren in depth. Recently a similar band near the head of Mahakipawa Arm, about a mile and a half south of Moetapu Point, has been prospected. This strikes north, dips east at 55°, and on the surface shows 25 ft. or more of quartz stained with iron, manganese, and, rarely, copper, and containing gold in small amount.

Top Valley.—As early as 1882 a quartz lode is reported to have been found near Armchair Creek. But this discovery does not seem to have been followed up, and lodes are not again mentioned in the official reports as occurring in the district till 1898, when several outcrops are reported on the ridge between Top Valley and Armchair Creek. By 1900 the Jubilee Co. had erected a ten-head mill and put through a small crushing; but for further particulars of the history of the area Downey's account (5; pp. 10–2) should be consulted.

The schists in this locality have a regional north-east strike and a north-west dip. A series of lodes striking north-west and dipping north-east extends along the Jubilee ridge for a mile or more, the most important, the Jubilee, occurring at the south end of the series. In this locality there are three parallel lodes from which ore has been mined.

The most south-westerly is the Morayshire lode. In 1912 a winze was sunk on this lode and from the vein stuff extracted from the winze 2 tons of scheelite was picked out. The winze is on the ridge of a spur between two gullies, little more than 2 chains apart. A few feet west of the winze an outcrop shows 3 in. of quartz on the hanging-wall of 3 ft. of crushed and sheeted schist containing irregular veinlets of quartz. On rock continously exposed along a track on the far side of the gully east of the winze one or other, or both, of two breaks, a few feet apart and little more than joints, may represent the lode. An adit 180 ft. long was driven under the winze and showed the lode to be split into stringers of no value. Apparently the narrow shoot of ore under the ridge disappeared in depth.

The Sylvia adit (so named by the present lessee, Captain H. E. Humphreys) is about 400 ft. above the valley-floor and is driven north-north-east as a crosscut for about 480 ft. It cuts the lode at 160 ft. from the entrance. This vein, which is about 500 ft. west of the Morayshire, was driven on for about 80 ft. north-west, and at the end shows a quartz vein up to 4 in. wide in broken rock between well-defined unshattered walls of oxidized schist. Eastward the level is open for about 100 ft. following a vein of quartz up to 18 in. thick. As judged from the collapsed workings on the surface this level was probably extended over 250 ft. from the crosscut. This ore-body is reported to have been stoped underhand in parts to 30 ft. below the level.

The principal ore-body of the Jubilee Claim, about 1,300 ft. north-east of the Sylvia, has been explored by a winze from the outcrop and two adits, respectively 125 ft. and 360 ft. below the top of the winze. At the outcrop surface indications are that the ore has been stoped for at least 250 ft. north-west from the winze. The stoped ground is open to a depth of about 60 ft. down the winze, and in places to a like distance north-west; the walls, though weathered, are of strong, unshattered schist and stand well. A remnant of ore at the outcrop shows 3 ft. of clean quartz without selvage, though readily separable from the walls. In places the lode seems to have been up to 6 ft. thick or more.

No. 1 adit, which reaches the lode about 300 ft. from the entrance, has a north-north-west course and crosses several displacement planes which strike north, or a little east of north, and dip west at from 50° to 80°. About 210 ft. from the entrance a stronger parallel break crosses the level, and for 50 ft. or 60 ft. onward the schist is broken and, in places, sheeted. Another decided fault is then crossed showing brecciation, sheeting, and pugging of the schist. The lode in this part appears to narrow in beyond the fault for a few yards; the drive is open for about 150 ft. farther. For much of this length an irregular cavity, from which ore has been extracted, extends up to 30 ft. above the level. Farther on, the level for an unknown distance and the unfilled stopes have collapsed. A drive follows the second fault for about 30 ft., and exposures along this and the main level show that the lode is folded into a rather sharp syncline, which pitches northward. A vertical rise from the point where the first fault crosses the level to the bottom of the winze from the outcrop is reported to have passed through a flat-lying quartz vein about 20 ft. above the level; if the syncline continues upwards, this quartz could well be in its trough. The interpretations given to the facts so far as known are that a fault striking nearly north and dipping 60° west severs the lode, which strikes north-west and dips north-east at 60°; that the block containing the worked part of the lode west of the fault is relatively depressed; and that the rock, together with the contained lode adjacent to the fault, were dragged and deformed during the movement into a fold. If this explanation be correct a horizontal plane should cut the lost part of the lode on the east side of the fault-zone farther north than it does the known part of the lode on the west side of the fault-zone. The end of the drift that follows the fault first encountered in the adit for about 110 ft. northward is probably the point in the present excavations nearest to the lost part of the lode.

No. 2 adit, 235 ft. lower than No. 1, extends north-north-west for 530 ft., then for 150 ft. follows a strong "head" parallel with the lode in No. 1 adit and dipping north-east at 30°; the drift then turns nearly at right angles along another break striking a little east of north and dipping west at 60°. At the end of the level is a formation striking north-west, dipping north-east at 75°, and containing several veinlets of quartz. A rise at this point extends back over the level and is said to have connected with a winze on the lode below No. 1 adit. Probably the same formation is cut in the branch of the adit that extends north-east from the point where the first strong head is encountered.

No ore was obtained in No. 2 adit. The break followed by the west branch of the adit is approximately parallel with, has a similar dip to, and is in the correct position to correspond to the most easterly strong facture of the fault exposed in No. 1 adit. The formation containing quartz veins cut in both branches of No. 2 adit and the strong north-west striking head are parallel with the lode and are probably fractures formed by the same stress as formed the lode-fracture. On the interpretation given of the facts the lode-fracture lies farther to the north than the No. 2 adit has yet penetrated.

The fissures of the Jubilee, Sylvia, and Morayshire lodes are in places filled with crushed and sheeted rock or there is a narrow band of pug between the quartz and the wall; evidently displacement occurred along the fissure. Probably, however, the movements were not great or the stresses causing the fracture not intense, for the walls, in general, are not seamed with quartz veinlets or pug-filled partings. The fault in the Jubilee adits shows decidedly greater crushing; the disturbed zone is 50 ft. wide, in which the schist is brecciated sheeted, pugged, and darkened by the crushing and spreading-out of the graphite flakes in the rock. There are, besides, many planes of minor movement between the fault and the entrance of the adit. Veinlets of non-auriferous quartz up to an inch wide occur in the fault. The ore of the three lodes, so far as explored, is oxidized, but the adits show that oxidation is confined to within a foot or so of the lodes.

Half a mile north-west of the Jubilee lode, and in line with it, a series of fractures have been explored by numerous trenches and a couple of adits. The fractures, which contain quartz and formation, strike north-west and dip 45° to 60° to the north-east. Five samples the writer took contained less gold than a pennyweight per ton, and the Inspector of Mines in 1903 reports that a crushing of 10 tons gave very poor results. Nevertheless, the bed of Jackson's Creek, which has its east source in this area (Just-for-Luck Claim), has been worked throughout its length, the alluvial miners being reputed to have done well and to have got much rough gold.

None of the other claims in the neighbourhood, on several of which a good deal of prospecting has been done, was visited. The Baden Powell Claim adjoins the Just-for-Luck and is on the same line. The Wellington, on which at least two adits were driven, is a mile and a half upstream from the Jubilee and lies on the east side of the valley west of the Jubilee line. Tasman's Choice and the Duke of Cornwall, on both of which a good deal of prospecting has been carried out, are in the Armchair basin. Downey describes the former, which lies about 60 chains east of the Jubilee workings (5; pp. 11–2).

Endeavour Inlet.—Nothing can be added to the accounts of the Endeavour Inlet antimony deposits by S. H. Cox (Rep. Geol. Explor., 1874–6, No. 9, 1877, pp. 2–6; A. McKay(19); J. Park (R.G.E., 1888–9, No. 20, 1890, pp. 60–63); and J. Hector(13).

AGE AND ORIGIN OF THE LODES OF OTAGO AND MARLBOROUGH.

(By J. Henderson.)

Introduction.

The age of the lodes of the Marlborough district is not certainly known. Clearly they were formed after the rocks had been metamorphosed, and since gravels hundreds of feet above local base level contain alluvial gold the lodes are probably older than the Pleistocene. Geologists who have examined both regions find striking similarities in the schists of Marlborough and Otago. The resemblances of the lodes, which are of unusual type, are equally strong, and it seems reasonable to suppose that they were formed during the same period and under similar conditions. In Otago auriferous lodes contributed detrital gold to conglomerates of undoubted Upper Cretaceous age and, as the great majority of the lodes strike north-west parallel with the folds of the early and middle Mesozoic strata, which occupy large areas south-west and north-east of the schist region, most geologists consider that the lode fissures were formed during the mountain-building movements of the early Cretaceous. During this orogeny the then relatively unconsolidated Mesozoic beds were sharply folded, whereas in the adjoining resistant schist mass the stresses produced narrow shear zones and irregular belts of sheeted rock. Conditions are similar at the northern end of the South Island, where pressure active during the same general period strongly folded and overturned the Triassic and Permo-Carboniferous strata adjoining a large schist terrain in which, as in Otago, the schistosity planes have strikes and dips persistent over large areas. In Marlborough the lode fissures in the schists strike at right angles to the fold axes, but this does not preclude the possibility of their causal connection with the crustal stresses that produced the folds. Without exception the lodes worked or seriously prospected lie in a narrow belt, seventy miles long and five miles wide, extending from Cape Jackson to Mount Patriarch. In a general way this belt is parallel with the following major structures of the region to the west—(*a*) The folds of the Maitai strata; (*b*) the basic intrusions that extend from Dun Mountain to Red Hills; and (*c*) the Waimea fault-zone. Possibly this belt is an incipient fold or zone of stress produced in the resistant schistose rocks by the same earth forces that folded the weaker rocks to the west. On the other hand, the lode-belt is oblique to and is crossed by the Wairau, Queen Charlotte, and Kenepuru faults. The facts suggest that the lode-fissures in the schists are in some way connected with, and were formed at the same time as, the earth structures of the non-schistose area to the west.

Another hypothesis is that two periods of mineralization occur in Otago, the first connected with the early Cretaceous orogeny and the second with that of the late Tertiary. Lodes of the first mineralization yielded the detrital gold of the schist conglomerates of Lawrence and of the quartz

conglomerates of Otago, both of which formations contain no detrital scheelite. The second orogeny gave rise to the basalts of the Maniototo basin and many other points; the alluvial cinnabar, widespread in the younger gravels of Otago, is probably shed from the veins derived from the magmas that fed the surface flows. Cinnabar so far as not been observed in quartz veins carrying gold or scheelite, but the presence in these veins of stibnite, bournonite, and other low-temperature sulphides suggest that they may belong to a different stage of the same mineralization. Hitherto neither basalt nor cinnabar have been reported from Marlborough, though stibnite has been largely mined in the district. The late Tertiary crustal movements, though of a different type from those of the early Cretaceous, had the same general direction and the same explanation of the distribution of the lode-fissures is applicable to both.

Marlborough Lodes.—The fissures of the Marlborough lodes cut across the schistosity planes and maintain straight courses for long distances. Thus the Endeavour Inlet antimony lode has been traced for more than 140 chains, the Golden Bar for 90 chains, the Tasman's Choice for 30 chains, and Turner's Reef for 20 chains. In several localities, and probably in all, the ore-bearing fissure is one of several parallel fractures which may also contain ore-bodies.

The brecciated and crushed schist and the banded pug in the fissures show that the walls have moved relatively to one another, but in a general way the country on either side is not greatly broken or disturbed, though it may contain veinlets of quartz or calcite. Even in the sheeted zones the schistosity planes show little distortion or drag. The ore is easily mined—the stopes generally are not filled, and the walls of considerable stopes stand unbroken after the timber is decayed; these facts indicate that the wall rocks are but little crushed.

The quartz of the veins may be massive, banded with micaceous seams, or contain fragments of country of all sizes. It may extend from wall to wall, have a clay selvage on one or both sides, but is everywhere readily separable from the walls. Usually the veinstone is iron-stained and black manganese oxide may occur near the surface. Vugs lined with small quartz crystals are common. Many fragments of country in the veinstone are silicified, and at one point at Wakamarina the whole lode consisted for the most part of silicified crushed schist (15; p. 14). Calcite is obviously present in the deep unoxidized part of the Wakamarina lode. Pyrite is reported in depth in most of the lodes but is nowhere abundant, and arsenical pyrites is rare. Stibnite occurs abundantly at Endeavour Inlet and has been found, apparently as surface-fragments, at Deep Creek. No other sulphides have been reported.

Scheelite is a commercial constituent of the Golden Bar lode and it occurs in many of the Top Valley veins. Some years ago Mr. J. M. Cadigan, an expert prospector, marked on a map in this office the distribution of detrital scheelite as noted during his prospecting expeditions in the area west of the Kaituna Valley. He found scheelite sand in the wash of most of the streams draining from schistose rocks. They include several sources of the Pelorus River, most of the south side tributaries of the Wakamarina, and the Atahaua, Ngahu (Rocky), and Okuramio branches of the Kaituna; he also found it in the basins of Pine Valley, Timms, Armchair, and Top Valley Streams, as well as in several of the gullies descending from Mount Patriarch. Detrital scheelite seems to be as widespread over the schistose rocks as alluvial gold, though it has not been reported from the area east of the Kaituna basin; possibly it has not been looked for in that region.

The quartz veins of Marlborough are, in general, not rich in gold, though highly auriferous ore has been found both on the outcrops and hundreds of feet below the surface. Such ore is usually iron-stained and friable, free gold occurring on clay selvages or on partings in the quartz. Very little is known of the distribution of the gold in the poorer ores or in depth. Assays of vein material from Marlborough show that wherever it is auriferous it is also argentiferous, and that where there is no gold there is also no silver. This suggests that the silver is present not in a separate mineral, but alloyed with gold. Generally there is from six to ten times as much gold as silver, but in samples from the Moetapu area silver occurs in larger proportion. Marlborough alluvial gold seems to be about 930 fine, but no analyses are available to show with what metal it is alloyed.

Otago Lodes.—The writer has had the opportunity of examining in Otago only the quartz veins of Conroy Gully and Oturehua, lodes that, in general appearance and surroundings, closely resemble those of Marlborough. Descriptions of other Otago lodes by Ulrich, Rickard, McKay, Wilson, Park, Finlayson, Marshall, and Williamson confirm this view, though some differences, probably unimportant, appear. In some of the Otago lodes the amount of crushed rock between the walls seems to be greater than in the Marlborough lodes and the disturbance of the adjacent country more noticeable. The lodes of both regions yield the same minerals in commercial amount—gold, scheelite, and stibnite—and, in addition to pyrite, many Otago lodes contain arsenopyrite fairly commonly, and, from others, galena, zinc-blende, and bournonite has been reported in small amount. In general, the similarity in country, in occurrence, and in mineral association suggests that the lodes of Marlborough and Otago were formed under similar conditions and proof of origin in one region would be accepted for both.

Geneses of the Lodes.—Two origins for the lodes have been advocated—one that they are magmatic, and the other that they are due to processes of lateral secretion. The evidence is indefinite and in part contradictory. The metallic sulphides and the scheelite suggest that heated solutions rising from deep-seated masses of igneous rock formed the lodes, and one observer attempts to show that the wall rocks are sericitized. On the other hand, the close connection of the ore-bodies with the present topography suggest that surface solutions played an important part either in concentrating the valuable minerals from lean deposits of magmatic origin or in leaching gangue and minerals from the surrounding country.

Finlayson (8 ; pp. 118–19 and 9 ; 69–70) made chemical analyses of the " altered " rock of a number of Otago lodes and compared them with analyses of " unaltered " rock. He interprets the results as showing that sericitization has occurred. He bases his argument on two quite unproved assumptions—the first that the alumina of the rock remained constant during alteration, and the second that each pair of analyses is of the same stratum of rock. The analyses show that the " altered " rock has lost silica, iron-oxides, and lime, and gained pyrite. Two sets show gains in potash and two show losses, so that if the sericite in all samples contains a similar percentage of potash, in two samples the proportion of sericite increased and in two it decreased. The principal alteration is the removal of silica and lime and as the mines are above the drainage-level of each locality surface waters probably decomposed the feldspars and leached out the lime and silica. In No. 3 adit of the Empire City Claim at Wakamarina, and in the low level of the Golden Progress Mine, Oturehua, the present writer detected no change in the country near the lode except what could readily be attributed to crushing.

The metallic sulphides and the scheelite present in the lodes suggest that they are of magmatic origin, and the general appearance of the veins strongly recalls that of hydrothermal deposits directly connected with igneous rocks. As before mentioned, the lodes, on this hypothesis, may be either of early Cretaceous or of late Tertiary age.

If the former, the absence of outcrops of the igneous rocks that furnished the hydrothermal solutions has to be explained, as well as the absence of scheelite in the late Cretaceous and Tertiary conglomerates. The country of the lodes had been changed into schist before the lodes were formed, and the only known post-metamorphic igneous rocks penetrating the Otago schists are, first, the later Tertiary volcanics, which on the hypothesis now considered are later than the lodes ; and, secondly, the three, probably connected, basic igneous masses outcropping respectively in the basins of Moke Creek (7 ; p. 77) Springburn (26 ; pp. 28–9) and Otama Valley (p. 79, above).* Boulders of igneous rock, almost certainly derived from the extensive Otama mass, occur commonly in the Mesozoic conglomerates of the nearby Hokanui Hills, though quartz pebbles and alluvial gold are unknown. Had the Otama igneous mass given rise to auriferous lodes detritus from the veins would certainly have been as widely spread as fragments from the plutonic outcrops. Obviously, then, the Otama mass and the possibly connected serpentines at Springburn and Moke Creek are unlikely sources for the Otago quartz veins. Finlayson (9 ; p. 84) points out that the resemblances of the Otago lodes among themselves " indicate a pretty uniform degree of segregation beneath," and the subjacent magma must therefore have extended from Glenorchy to Waipori (110 miles) and from Waitahuna to Macraes (60 miles). In view of the enormous denudation during late Cretaceous and early Tertiary times, and of the vast crustal displacements of the late Tertiary, the absence of any exposure of the igneous rock supposedly underlying such a large area is indeed astonishing. The last statement is equally applicable to Marlborough, in which region no igneous rocks are known to intrude the schists.

During the Mesozoic earth-movements basic and ultrabasic igneous rocks invaded the folded sediments. Here belong the intrusions of the Nelson highlands that extend from D'Urville Island through Dun Mountain to the Red Hills, as well as the intrusions of the Spenser Mountains, of the Southern Alps, and of north-west Otago. These igneous masses, though not themselves directly connected with the hydrothermal veins of Marlborough and Otago, indicate the existence of a deep-seated magma. Thus the veins, though not bound to known igneous intrusions on this hypothesis, may owe their origin to the distant influence of a great magma basin, perhaps the sima itself. The objection to this hypothesis is that the veins of West Nelson and Westland—that is, the areas between Marlborough and Otago—though they carry gold and metallic sulphides, contain no tungsten minerals. If the scheelite veins of Marlborough and Otago had their source in the magmas active during the early Cretaceous orogeny, the vast granite batholiths of the West Coast, differentiated from this magma, should have given rise to tungsten-bearing veins more probably than the basic and ultra-basic masses of Dun Mountain and north-west Otago, for the formation of magmatic-ore deposits is a process which cannot be separated from other events of magmatic differentiation, and, so far as known, all deposits of primary tungsten ore are connected with acid rocks.

The Pleistocene and Recent gravels of streams draining the schist areas of Marlborough and Otago commonly contain detrital scheelite. If gold-scheelite lodes were subject to erosion during the late Cretaceous and Tertiary times scheelite must have accumulated with alluvial gold in suitable localities. Richly auriferous river-gravels of these periods, now converted to schist and quartz conglomerates, contain no scheeltie. Gannet(10) has shown that, contrary to general opinion, tungsten minerals are readily attacked by surface waters and form soluble salts and colloidal compounds, which may not be redeposited close at hand. The data are rather scanty, but it seems possible for any scheelite contained in old gravels to have been removed by circulating surface waters.

The next hypothesis—that the gold-scheelite lodes of Otago are derived from the igneous magma that was the source of the basalts of Otago Central—implies that a similar magma underlies the schists of Marlborough. Basalt flows are known at many points in Otago ; pebbles in stream-gravels indicate an even wider distribution. And if the cinnabar, so widespread in the province, had its origin in the same magma, fluid rock and igneous emanations reached the greater part of the schist area. On this hypothesis an earlier series of pre-Tertiary veins that yielded the greater part of the alluvial gold must be presupposed in addition to the gold-scheelite veins. In Otago some gold-veins contain no scheelite and there are other points of difference, but the similarities of all the veins are many and close and

* See also N.Z.G.S., 27th Ann. Rep., 1933, p. 18.

are readily explicable as due to the veins belonging to slightly different phases of the same mineralization. Park (27 ; p. 94) points out that scheelite-bearing veins in the Queenstown district are found only in the upper, less-metamorphosed schists. In Otago and Marlborough such veins are commoner and of higher grade in the upper schists than in the lower, a reasonable explanation being that scheelite-gold ore, deposited at a shallower depth than gold ore, was removed during the late Cretaceous peneplanation. This, of course, supports an early Cretaceous age for the mineralization. The objections to the late Tertiary hypothesis are strong and, but for the fact that the veins closely resemble those of Atolia in California, this hypothesis would not have been mentioned. At Atolia, in narrow fissure veins consisting of quartz and a small amount of calcite, occur gold and scheelite, together with arsenopyrite, pyrite, stibnite, galena, and cinnabar. The textures are fine-grained, druses occur, inclusions of wall rock are common, and the ore-bodies are found only near the surface. These deposits were formed in "Upper Miocene time by hot, ascending alkaline solutions of magmatic origin, the deposition occurring close to the surface under conditions of relatively low pressure and low temperature. Such deposits may be termed epithermal" (16 ; p. 77). There seems to be no valid objection on general grounds to postulating an epithermal origin for some tungsten ores. For though tungsten minerals are "common in pegmatites and in lodes formed at considerable depths, the most valuable deposits in the United States are lodes formed by ascending hot waters at moderate or shallow depths" (6 ; p. 525, see also 32).

The relation of the ore-bodies to the present topography suggests that surface waters formed them either by concentrating primary lean deposits or by leaching and redepositing gangue and minerals from the surrounding rocks. In Marlborough the lodes "are for the most part found at considerable altitudes above sea-level" (*N.Z. Mining Handbook*, p. 366, 1906). The ore-bodies occur in ridges and on hill slopes and the workings are above local drainage-level ; the only exception is the Golden Point, in which a winze penetrated a few feet below the sea, but here, until the drowning of Queen Charlotte Sound, the greatest depth reached by mining was well above base-level. The ore of the district is, on average, of low grade, and, except at Wakamarina, work became unprofitable and ceased before the bodies of quartz were bottomed. At Wakamarina a well-explored strong quartz ore-body, continuous over a length of 2,200 ft., is nowhere known to extend more than 240 ft. from the surface. For 950 ft. this ore-body definitely bottoms in a formation of crushed and sheeted rock filling the lode-fissure and containing only thin veinlets of quartz.

In Otago, in the majority of the lodes, the workings are above adjacent streams. So far as can be made out from the imperfect records available, the chief mines below nearby drainage channels are the O.P.Q., Canton, Golden Progress, Premier, and Phœnix Mines. The O.P.Q. and Canton lodes at Waipori cut across a low schist ridge lying between flats, of which the gravel-filling of that on the northern side is at least 150 ft. deep. The shafts of the mines are respectively 285 ft. and 180 ft. deep (23 ; pp. 37–8, 65) but the heights of the shaft collars above the flats are not known so that it is doubtful if the lowest workings even of the O.P.Q. are below the Pleistocene base-level. The Golden Progress Mine is near Oturehua, at the northern end of Ida Valley. The shaft, 240 ft. deep, is half a mile up a small gully draining from Rough Ridge to the flats which may be lower than the deepest workings in the mine. The deepest workings of the Premier Mine, near Macetown, are apparently 320 ft. below the main adit. No. 5 level of the Phœnix (later Achilles) at Bullendale seems, from Wilson's account (C.–3, 1897, p. 122), to be 387 ft. under the lowest adit. Both mines are in mountainous country ; the Goldburn, near the Premier, rises 790 ft. in about two miles, and the grade of Skipper's Creek, near the Phœnix, must be even sharper. Both lodes outcrop high on precipitous slopes, and artesian effects in the ground-water circulation along them are probable.

From the above it is clear that in Otago as in Marlborough the vein-material so far exposed is likely to have been oxidized or otherwise affected by surface waters. In Marlborough all the auriferous ore was oxidized, generally it was easy to mine and fairly friable, owing perhaps to the removal of the calcite which seems to be present in small amount wherever the vein-material is unleached (19 ; p. 11). At the Endeavour Inlet Antimony Mine the most profitable ore was in the upper levels in country stained red with oxides of iron. In Otago the vein-stuff of many mines became too poor to work when sulphides appeared in quantity, but in others values extended at least some distance into the unoxidized zone.

Of the mines of the Cromwell district, Professor Park (26 ; p. 58) writes, "it is a noticeable feature, and one common to many of the lodes on this "[Carrick]" and the Bendigo field, that the underhand stope, by means of which the ore was beaten out, does not descend to a depth of 20 ft. or 30 ft. throughout its whole length," and he gives a sketch of the Crown and Cross lode showing stoping to a depth of about 15 ft. over a length of 11 chains. Along the Cromwell lode, the most profitable in Otago, good ore extended horizontally for 1,600 ft. and to a depth of 400 ft. (26 ; p. 56, map). L. O. Beal (1 ; p. 201), in preparing a geological section of the Nenthorn field after its abandonment, found "that the shoots of gold had been almost horizontal, whereas the companies looked for the shoots of gold going down perpendicularly." Without giving further tedious details of other fields, one can say that the ore-bodies of the Otago lodes have much greater lateral than vertical extent. This is also true of the Wakamarina (5 ; p. 14) and Endeavour Inlet lodes, the only well-explored veins in Marlborough. The ore-bodies of the greatest vertical range occur in the precipitous highlands about Macetown and Skippers. One shoot in the Premier is stated to have a vertical range of 3,300 ft. (27 ; p. 77), and one in the Phœnix of 1,200 ft. (27 ; p. 85). Unfortunately, from the data available the distance of the ore from the existing surface cannot be determined.

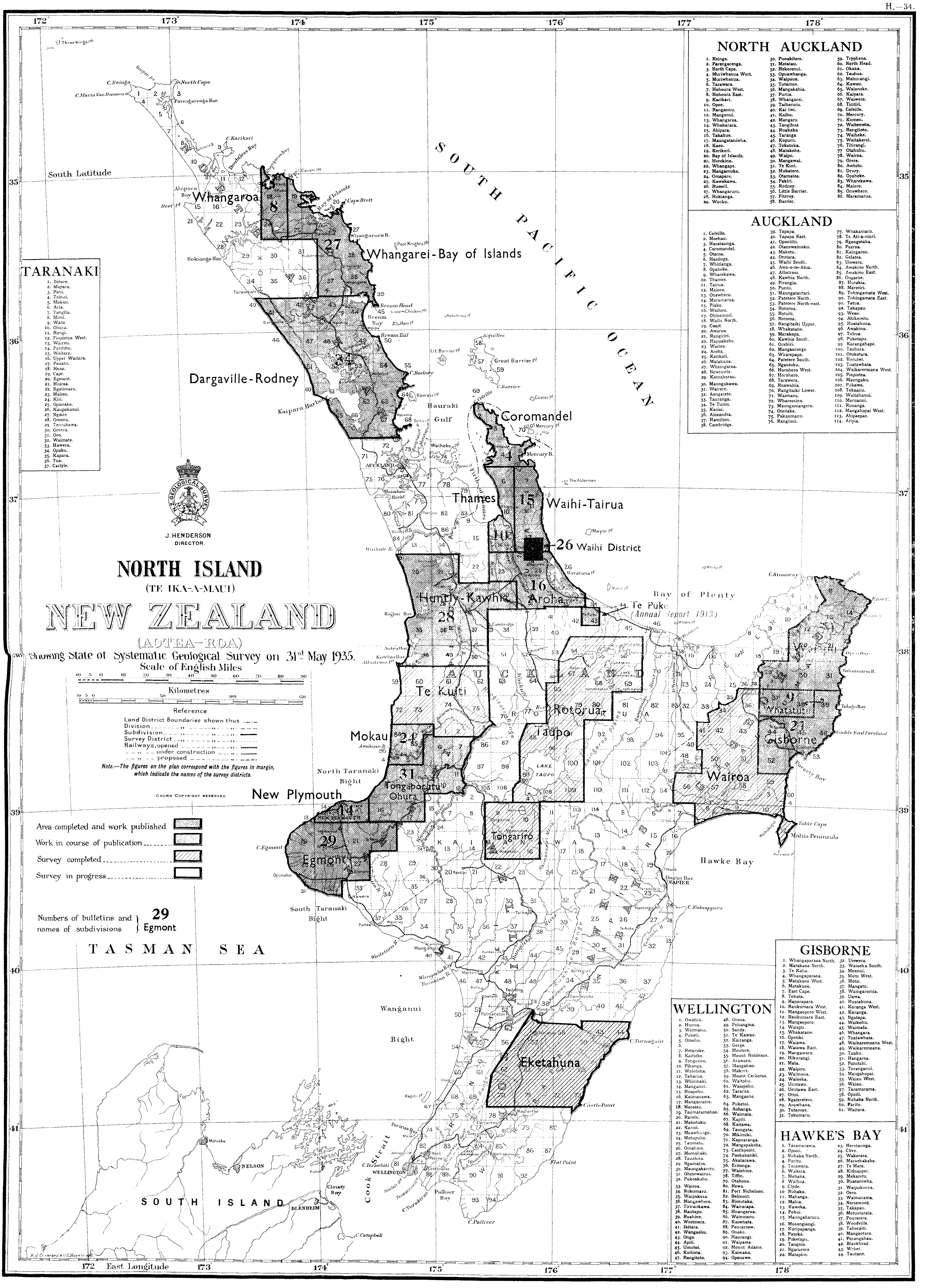
Park (27 ; p. 64) and Finlayson (9 ; p. 83) stress the importance of secondary enrichment in forming pay-ore close to the surface, and without doubt the "paint" and "mustard" gold occurring on clay selvages, in drusy cavities, and along partings in such ore are due to circulating surface waters.

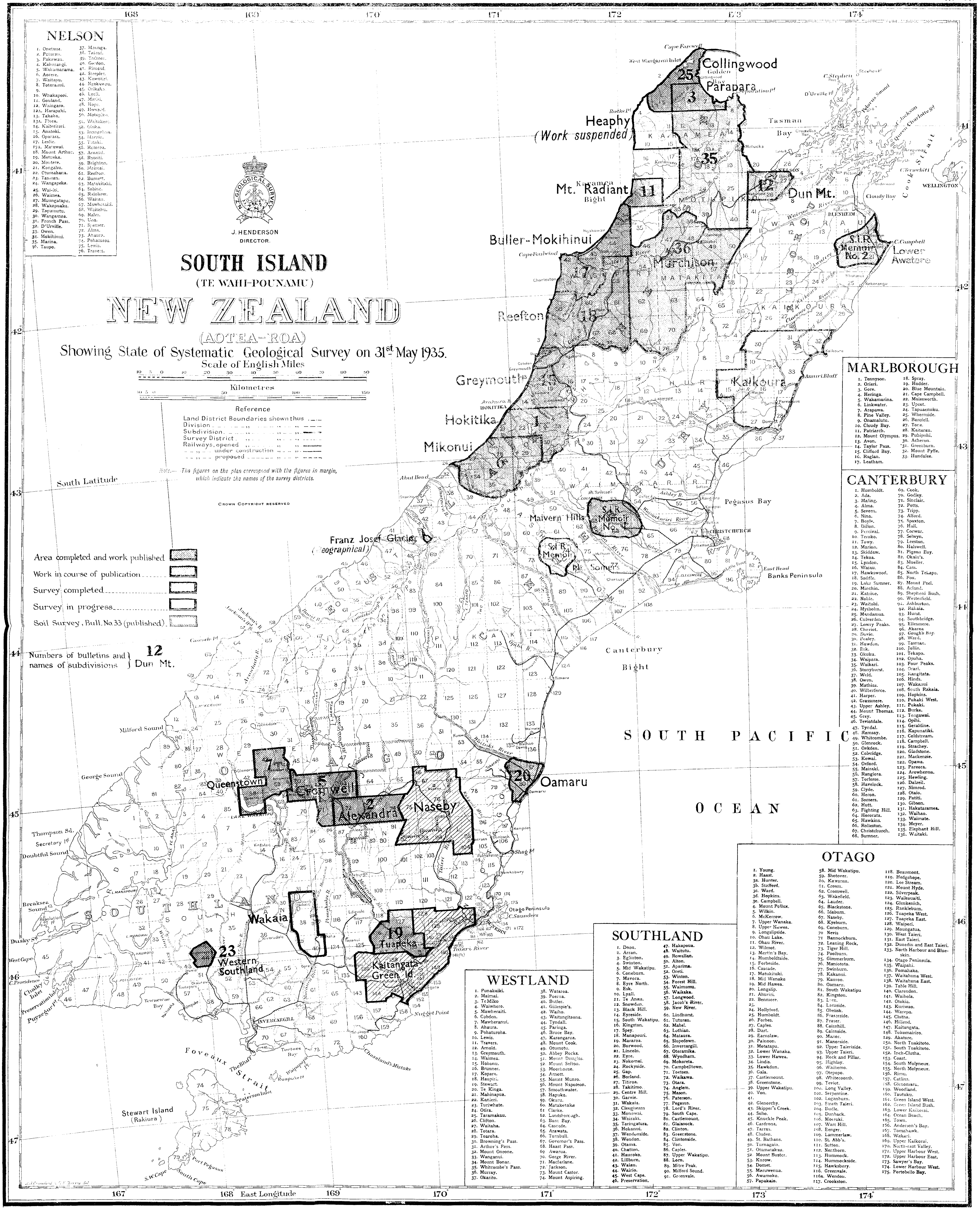
Again Park's section (26 ; p. 56) of the Bendigo stopes shows graphically how pay-ore, extending from the surface, is separated by a zone of richer ore from the unprofitable veinstone occurring along the lode in depth and farther in from the hill-side on which it outcrops. Finlayson (9 ; pp. 77–8) adduces good evidence for downward enrichment of gold and the presence of secondary sulphide at Barewood. The chemistry of the solution and redeposition of gold and sulphides by surface waters is so well known that the only points worth noting are that the schists contain manganese, and that the oxides of manganese that seem necessary to the solution of gold are present in the upper parts of many lodes. The occurrence of scheelite as veinlets bordering and cutting across quartz ore and as bunches on the walls at cross-fractures (8, p. 112 ; 15, p. 14 ; 33, p. 117) suggest secondary deposition. The fact that scheelite is soluble in surface waters has already been noted.

On the lateral-secretion hypothesis the ore-bodies are ascribed to the familiar processes of weathering and to the feeble but sustained circulation of atmospheric waters. Some of the facts of occurrence are more readily explained by this theory than by the magmatic or any of its variants. The quartz ore-body of the Wakamarina lode, completely stoped out over a length of 1,350 ft. and partly stoped out for a further 900 ft. to an average depth of 200 ft. from the surface, grades downward, in the height of a stope (7 ft.), from quartz 6 ft. to 12 ft. thick and containing only minor bands of crushed schist into a formation filling the lode-fissure and consisting of crushed and sheeted rock seamed with a few veinlets of quartz (15 ; p. 14). In the adit, 15 ft. below, the amount of quartz is decidedly less, a fact suggesting its complete disappearance at slightly greater depth. The bottom of the ore-body remains about 15 ft. above the adit for 900 ft. ; farther on, roughly following the contour of the surface, it descends and passes below the adit in about 50 ft. In all this distance there is nothing to suggest the existence of a significant channel by which ore-solutions rose from below through the crushed rock filling the fissure, and there is nothing to suggest a change of structure or composition of the rather uniform sub-schists of the country that might tend to alter conditions of ore accumulation so abruptly. In Otago, Marshall (23 ; p. 47) describes the scheelite-bearing vein between Nardoo and Lammerlaw Creeks as completely disappearing at a depth of 30 ft., and Gordon (C.–2, 1885, p. 10) reports that the Royal Oak lode, Carrick Range, became unpayable at a depth of 70 ft. and cut out entirely at 150 ft. Both these occurrences, however, may be due to local pinching, and the amount of prospecting where the fissure was barren is not stated.

Conclusion.—To sum up, the gold-scheelite lodes may be (1) primary deposits, (2) secondary concentrations of lean primary deposits, or (3) lateral secretion deposits. The ore-bodies are all so closely connected with the surface that if the lodes are primary the mineralization must have taken place in the late Tertiary. There are so many difficulties in this view that, in the writer's opinion, this hypothesis must be rejected. All the deposits show definite evidence of secondary enrichment and, on the second hypothesis, the lean primary deposits may reasonably be considered as connected with the mountain-building movements of the early Cretaceous. This hypothesis adequately explains the location and characteristics of the ore-bodies and the distribution of the alluvial gold in time and space. But there are some facts which, though of the negative type, are decidedly disconcerting. There is, first, the absence of any igneous rocks that could have supplied the ore-bearing solutions over the whole of Otago and Marlborough, and this, notwithstanding enormous denudation and great crustal deformation, since the supposed intrusion. Secondly, the same orogeny to which the scheelite-bearing veins are attributed also folded the strata of the highlands extending from Otago to Marlborough ; no trace of scheelite is known over this large area. Again, lodes of West Nand and western Nelson, though derived from the granite batholiths intruded during this period of folding, contain no scheelite or other tungsten mineral. Otherwise the minerals are the same as those of the lodes of Otago and Marlborough. If the scheelite belongs to a high part of a depth-zone series of mineral deposition the upper scheelite-bearing parts of the lodes were eroded long ago. The series in downward sequence would then contain the gold-scheelite lodes of Otago and Marlborough, followed by the gold-lodes of Macetown and Skippers, and then, after considerable interval, by the gold-lodes of the West Coast. On this hypothesis the magmatic solutions that reached the schists were far from their source, were widely diffused in shatter zones, were relatively cool, were unable to replace all the crushed rock of the fissures, and did not greatly alter the wall rocks. The pyritized shear-zone extending east from Bendigo across the Dunstan Range and described by Ulrich (30 ; pp. 209–10) and Park (26 ; pp. 56–7) may be regarded as a late phase of this mineralization. The secondary changes brought about by the long-continued action of surface waters played an important part in forming the ore-bodies, concentrating the minerals diffused in the crushed rock of the fissures and in the adjacent country, and as well as perhaps segregating the gangue from the same sources. The secondary processes may altogether have effaced the features of the lodes connected with their primary genesis.

On the last-mentioned hypothesis the metals and sulphur disseminated through the country near an ore-bearing fissure are derived from solutions rising from a deep-seated source, whereas the lateral secretionists claim that the gold and other metals present in minute quantities in all rocks may, under favourable conditions, be concentrated to form ore-bodies. Don's classical investigations are often quoted as disproving this theory. He showed that gold was detectable by the methods he used only in rocks containing sulphides, and that sulphides and gold were most abundant near lodes (4 ; p. 580). Wagoner (31 ; pp. 809–10), who used much more refined methods than those available to Don, found gold in all the rocks he investigated. The late Professor D. B. Waters found traces of gold in nearly all the samples he assayed from the quartz lenticles in the Otago schists (23 ; p. 42). That the lodes of Otago and Marlborough were formed by the processes of lateral secretion cannot be considered impossible, but the writer prefers to believe that the ore-bodies are secondary concentrations of lean primary deposits formed by cool far-wandering magmatic (telemagmatic) solutions.


J. HENDERSON
DIRECTOR.
NORTH ISLAND
(TE IKA-A-MAUI)
NEW ZEALAND
(AOTEA-ROA)
Showing State of Systematic Geological Survey on 31st May 1935.
Scale of English Miles
Kilometres
Reference
Land District Boundaries shown thus
Division
Subdivision
Survey District
Railways, opened
" under construction
" proposed
Note.—The figures on the plan correspond with the figures in margin, which indicate the names of the survey districts.
CROWN COPYRIGHT RESERVED
Area completed and work published
Work in course of publication
Survey completed
Survey in progress
Numbers of bulletins and names of subdivisions
29
Egmont
SOUTH PACIFIC OCEAN
TASMAN SEA
SOUTH ISLAND
South Latitude
East Longitude
8 Whangaroa
27 Whangarei-Bay of Islands
Dargaville-Rodney
4 Coromandel
Thames
15 Waihi-Tairua
10
26 Waihi District
16 Aroha
44 Te Puke (Annual Report 1913)
28 Huntly-Kawhia
Te Kuiti
Rotorua
Taupo
24 Mokau
31 Tongaporutu Ohura
14 New Plymouth
29 Egmont
Tongariro
9 Whatatutu
21 Gisborne
Wairoa
Eketahuna
Bay of Plenty
Hawke Bay
North Taranaki Bight
South Taranaki Bight
Wanganui Bight
Cook Strait
Hauraki Gulf
AUCKLAND
WELLINGTON
NAPIER
NELSON
BLENHEIM
NORTH AUCKLAND
1. Reinga.
2. Parengarenga.
3. North Cape.
4. Muriwhenua West.
5. Muriwhenua.
6. Tarawara.
7. Hohoura West.
8. Hohoura East.
9. Karikari.
10. Opoe.
11. Rangaunu.
12. Mangonui.
13. Whangaroa.
14. Whakarara.
15. Ahipara.
16. Takahue.
17. Maungataniwha.
18. Kaeo.
19. Kerikeri.
20. Bay of Islands.
21. Herekino.
22. Whangape.
23. Mangamuka.
24. Omapere.
25. Kawakawa.
26. Russell.
27. Whangaruru.
28. Hokianga.
29. Waoku.
30. Punakitere.
31. Motatau.
32. Hekerenui.
33. Opuawhanga.
34. Waipoua.
35. Tutamoe.
36. Mangakahia.
37. Purua.
38. Whangarei.
39. Taiharuru.
40. Kai Iwi.
41. Kaihu.
42. Mangaru
43. Tangihua
44. Ruakaka
45. Taranga
46. Kopuru.
47. Tokatoka.
48. Matakohe.
49. Waipu.
50. Mangawai.
51. Te Kuri.
52. Hukatere.
53. Otamatea.
54. Pakiri.
55. Rodney.
56. Little Barrier.
57. Fitzroy.
58. Barrier.
59. Tryphena.
60. North Head.
61. Okaka.
62. Tauhoa.
63. Mahurangi.
64. Kawau.
65. Waioneke.
66. Kaipara.
67. Waiwera.
68. Tiritiri.
69. Colville.
70. Mercury.
71. Kumeu.
72. Waitemata.
73. Rangitoto.
74. Waiheke.
75. Waitakerei.
76. Titirangi.
77 Otahuhu.
78. Wairoa.
79. Orere.
80. Awhitu.
81. Drury.
82. Opaheke.
83. Wharekawa.
84. Maioro.
85. Onewhero.
86. Maramarua.
AUCKLAND
1. Colville.
2. Moehau.
3. Harataunga.
4. Coromandel.
5. Otama.
6. Hastings.
7. Whitianga.
8. Opaheke.
9. Wharekawa.
10. Thames.
11. Tairua.
12. Maioro.
13. Onewhero.
14. Maramarua.
15. Piako.
16. Waihou.
17. Ohinemuri.
18. Waihi North.
19. Coast.
20. Awaroa.
21. Rangiriri.
22. Hapuakohe.
23. Waitoa.
24. Aroha.
25. Katikati.
26. Matakana.
27. Whaingaroa.
28. Newcastle.
29. Komakorau.
30. Maungakawa.
31. Wairere.
32. Aongatete.
33. Tauranga.
34. Te Tumu.
35. Karioi.
36. Alexandra.
37. Hamilton.
38. Cambridge.
39. Tapapa.
40. Tapapa East.
41. Opoutihi.
42. Otanewainuku.
43. Maketu.
44. Otutara.
45. Waihi South.
46. Awa-o-te-Atua.
47. Albatross.
48. Kawhia North.
49. Pirongia.
50. Puniu.
51. Maungatautari.
52. Patetere North.
53. Patetere North-east.
54. Rotorua.
55. Rotoiti.
56. Rotoma.
57. Rangitaiki Upper.
58. Whakatane.
59. Marakopa.
60. Kawhia South.
61. Orahiri.
62. Mangaorongo
63. Wharepapa.
64. Patetere South.
65. Ngautuku.
66. Horohoro West.
67. Horohoro.
68. Tarawera.
69. Ruawahia.
70. Rangitaiki Lower.
71. Waimana.
72. Whareorino.
73. Maungamangero.
74. Otanake.
75. Pakaumanu.
76. Ranginui.
77. Whakamaru.
78. Te Ati-a-muri.
79. Ngongotaha.
80. Paeroa.
81. Kaingaroa.
82. Galatea.
83. Urewera.
84. Awakino North.
85. Awakino East.
86. Ongarue.
87. Hurakia.
88. Marotiri.
89. Tuhingamata West.
90. Tuhingamata East.
91. Tatua.
92. Takapau.
93. Weao.
94. Ahikereru.
95. Ruatahuna.
96. Awakino.
97. Tuhua.
98. Puketapu.
99 Karangahape.
100. Tauhara.
101. Otukotara.
102. Heruiwi.
103. Tuatawhata.
104. Waikaremoana West.
105. Piopiotea.
106. Maungaku.
107. Pukawa.
108. Tokaanu.
109. Waitahanui.
110. Maruanui.
111. Runanga.
112. Mangahopai West.
113. Ahipaepae.
114. Aripia.
TARANAKI
1. Totoro.
2. Mapara.
3. Pahi.
4. Tainui.
5. Mokau.
6. Aria.
7. Tangitu.
8. Mimi.
9. Waro.
10. Ohura.
11. Rangi.
12. Piopiotea West.
13. Wairau.
14. Paritutu.
15. Waitara.
16. Upper Waitara.
17. Pouatu.
18. Heao.
19. Cape.
20. Egmont.
21. Huiroa.
22. Ngatimaru.
23. Mahoe.
24. Kiri.
25. Opunake.
26. Kaupokonui.
27. Ngaire.
28. Omona.
29. Taurakawa.
30. Omara.
31. Oeo.
32. Waimate.
33. Hawera.
34. Opaku.
35. Kapara.
36. Tua.
37. Carlyle.
WELLINGTON
1. Owatua.
2. Hunua.
3. Waimanu.
4. Puketi.
5. Omoho.
6.
7. Retaruke.
8. Kaitieke.
9. Tongariro.
10. Pihanga.
11. Waiotaka.
12. Taharua.
13. Whirinaki.
14. Manganui.
15. Ruapehu.
16. Kaimanawa.
17. Mangamaire.
18. Horotea.
19. Taumatamahoe.
20. Rarete.
21. Makotuku.
22. Karioi.
23. Moawhango.
24. Motupuha.
25. Taumata.
26. Omahine.
27. Momahaki.
28. Tauakira.
29. Ngamatea.
30. Maungakaretu.
31. Ohinewairua.
32. Pukeokahu.
33. Wairoa.
34. Nukumaru.
35. Waipakura.
36. Mangawhero.
37. Tiriraukawa.
38. Hautapu.
39. Ruahine.
40. Westmere.
41. Ikitara.
42. Wangaehu.
43. Ongo.
44. Apiti.
45. Umutoi.
46. Koitiata.
47. Rangitoto.
48. Oroua.
49. Pohangina.
50. Sandy.
51. Te Kawau.
52. Kairanga.
53. Gorge.
54. Moutere.
55. Mount Robinson.
56. Arawaru.
57. Mangahao.
58. Makuri.
59. Mount Cerberus.
60. Waitohu.
61. Waiopehu.
62. Tararua.
63. Mangaone.
64. Puketoi.
65. Aohanga.
66. Waimata.
67. Kapiti.
68. Kaitawa.
69. Taungata.
70. Mikimiki.
71. Kopuaranga.
72. Mangapakeha.
73. Castlepoint.
74. Paekakariki.
75. Akatarawa.
76. Eritonga.
77. Waiohine.
78. Tiffin.
79. Otahoua.
80. Rewa.
81. Port Nicholson.
82. Belmont.
83. Rimutaka.
84. Wairarapa.
85. Huangarua.
86. Wainuioru.
87. Kaiwhata.
88. Pencarrow.
89. Onoke.
90. Haurangi.
91. Waipawa.
92. Mount Adams.
93. Kaiwaka.
94. Opouawe.
GISBORNE
1. Whangaparaoa North.
2. Matakaoa North.
3. Te Kaha.
4. Whangaparaoa.
5. Matakaoa West.
6. Matakaoa.
7. East Cape.
8. Tokata.
9. Haparapara.
10. Raukumara West.
11. Mangaoporo West.
12. Raukumara East.
13. Mangaoporo.
14. Waiapu.
15. Whakatane.
16. Opotiki.
17. Waiawa.
18. Waiawa East.
19. Mangawaru.
20. Hikurangi.
21. Mata.
22. Waipiro.
23. Waimana.
24. Waioeka.
25. Urutawa.
26. Urutawa East.
27. Otipi.
28. Ngateretere.
29. Arowhana.
30. Tutamoe.
31. Tokomaru.
32. Urewera.
33. Waioeka South.
34. Moanui.
35. Motu West.
36. Motu.
37. Mangatu.
38. Waingaromia.
39. Uawa.
40. Ruatahuna.
41. Koranga West.
42. Koranga.
43. Ngatapa.
44. Waikohu.
45. Waimata.
46. Whangara.
47. Tuatawhata.
48. Waikaremoana West.
49. Waikaremoana.
50. Tuahu.
51. Hangaroa.
52. Patutahi.
53. Turanganui.
54. Mangahopai.
55. Waiau West.
56. Waiau.
57. Taramarama.
58. Opoiti.
59. Nuhaka North.
60. Paritu.
61. Waitara.
HAWKE'S BAY
1. Taramarama.
2. Opoiti.
3. Nuhaka North.
4. Paritu.
5. Tarawera.
6. Waitara.
7. Mohaka.
8 Waihua.
9. Clyde.
10 Nuhaka.
11. Mahanga.
12. Mahia.
13. Kaweka.
14. Pohui.
15. Maungaharuru.
16. Moeangiangi.
17. Kuripapanga.
18. Patoka.
19. Puketapu.
20. Tangoio.
21. Ngaruroro
22. Matapiro.
23. Heretaunga.
24. Clive.
25. Wakarara.
26. Maraekakaho.
27. Te Mata.
28. Kidnapper.
29. Makaretu.
30. Ruataniwha.
31. Waipukurau.
32. Oero.
33. Waimarama.
34. Norsewood.
35. Takapau.
36. Motuotaraia.
37. Pourerere.
38. Woodville.
39. Tahoraiti.
40. Mangaotoro.
41. Porangahau.
42. Blackhead
43. Weber.
44. Tautane.
R. J. Crawford & G. E. Harris del.


SOUTH ISLAND
(TE WAHI-POUNAMU)
NEW ZEALAND
(AOTEA-ROA)
Showing State of Systematic Geological Survey on 31st May 1935.
Scale of English Miles
Kilometres
N.Z. GEOLOGICAL SURVEY
J. HENDERSON
DIRECTOR.
Reference
Land District Boundaries shown thus
Division
Subdivision
Survey District
Railways, opened
under construction
proposed
Note.—The figures on the plan correspond with the figures in margin, which indicate the names of the survey districts.
CROWN COPYRIGHT RESERVED
Area completed and work published
Work in course of publication
Survey completed
Survey in progress
Soil Survey, Bull. No. 33 (published)
Numbers of bulletins and names of subdivisions 12 Dun Mt.
South Latitude
East Longitude
Collingwood
Parapara
Heaphy (Work suspended)
Mt. Radiant
Buller-Mokihinui
Murchison
Reefton
Greymouth
Hokitika
Mikonui
Dun Mt.
S.I.R. Memoir No. 2
Lower Awatere
Kaikoura
Malvern Hills
S.I.R. Memoir No. 1
Mt. Somers
Franz Josef Glacier (Geographical)
Queenstown
Cromwell
Alexandra
Naseby
Oamaru
Wakaia
Tuapeka
Kaitangata-Green Id.
Western Southland
SOUTH PACIFIC OCEAN
Tasman Bay
Cook Strait
Pegasus Bay
Banks Peninsula
Canterbury Bight
Foveaux Strait
Stewart Island (Rakiura)
Milford Sound
George Sound
Thompson Sd.
Doubtful Sound
Breaksea Sound
Dusky Sd.
Chalky Inlet
Preservation Inlet
Otago Peninsula
NELSON
1. Onetaua. 2. Paturau. 3. Pakawau. 4. Kahurangi. 5. Wakamarama. 6. Aorere. 7. Waitapu. 8. Totaranui. 9. 10. Whakapoai. 11. Gouland. 12. Waingaro. 12A. Harapaki. 13. Takaka. 13A. Flora. 14. Kaiteriteri. 15. Anatoki. 16. Oparara. 17. Leslie. 17A. Matawai. 18. Mount Arthur. 19. Motueka. 20. Moutere. 21. Kongahu. 22. Otumahana. 23. Tasman. 24. Wangapeka. 25. Wai-iti. 26. Waimea. 27. Maungatapu. 28. Wakapuaka. 29. Tapumutu. 30. Wangamoa. 31. French Pass. 32. D'Urville. 33. Owen. 34. Mokihinui. 35. Marina. 36. Taupo. 37. Maunga. 38. Tainui. 39. Tadmor. 40. Gordon. 41. Rimoul. 42. Steeples. 43. Kawatiri. 44. Ngakawau. 45. Orikaka. 46. Lyell. 47. Matiri. 48. Hope. 49. Howard. 50. Motupiko. 51. Waitakere. 52. Ohika. 53. Inangahua. 54. Maruia. 55. Tutaki. 56. Rotoroa. 57. Arnaud. 58. Roteiti. 59. Brighton. 60. Maimai. 61. Reefton. 62. Burnett. 63. Matakitaki. 64. Sabine. 65. Rainbow. 66. Waitau. 67. Mawheraiti. 68. Waitahu. 69. Rahu. 70. Una. 71. Spenser. 72. Alma. 73. Ahaura. 74. Pohaturoa. 75. Lewis. 76. Travers.
MARLBOROUGH
1. Tennyson. 2. Orieri. 3. Gore. 4. Heringa. 5. Wakamarina. 6. Linkwater. 7. Arapawa. 8. Pine Valley. 9. Onamalutu. 10. Cloudy Bay. 11. Patriarch. 12. Mount Olympus. 13. Avon. 14. Taylor Pass. 15. Clifford Bay. 16. Raglan. 17. Leatham. 18. Spray. 19. Hodder. 20. Blue Mountain. 21. Cape Campbell. 22. Molesworth. 23. Upcot. 24. Tapuaenuku. 25. Whernside. 26. Barefell. 27. Tone. 28. Kaitarau. 29. Puhipuhi. 30. Acheron. 31. Greenburn. 32. Mount Fyffe. 33. Hundalee.
CANTERBURY
1. Humboldt. 2. Ada. 3. Maling. 4. Alma. 5. Severn. 6. Nina. 7. Boyle. 8. Dillon. 9. Percival. 10. Terako. 11. Towy. 12. Marion. 13. Skiddaw. 14. Tekoa. 15. Lyndon. 16. Waiau. 17. Hawkswood. 18. Saddle. 19. Lake Sumner. 20. Minchin. 21. Katrine. 22. Noble. 23. Waitohi. 24. Mytholm. 25. Mandamus. 26. Culverden. 27. Lowry Peaks. 28. Cheviot. 29. Davie. 30. Bealey. 31. Hawdon. 32. Esk. 33. Okuku. 34. Waipara. 35. Waikari. 36. Stonyhurst. 37. Weld. 38. Owen. 39. Mathias. 40. Wilberforce. 41. Harper. 42. Grassmere. 43. Upper Ashley. 44. Mount Thomas. 45. Grey. 46. Teviotdale. 47. Tyndal. 48. Ramsay. 49. Whitcombe. 50. Glenrock. 51. Oakden. 52. Coleridge. 53. Kowai. 54. Oxford. 55. Mairaki. 56. Rangiora. 57. Torlesse. 58. Havelock. 59. Clyde. 60. Heron. 61. Somers. 62. Hutt. 63. Fighting Hill. 64. Hororata. 65. Hawkins. 66. Rolleston. 67. Christchurch. 68. Sumner. 69. Cook. 70. Godley. 71. Sinclair. 72. Potts. 73. Tripp. 74. Alford. 75. Spaxton. 76. Hall. 77. Corwar. 78. Selwyn. 79. Leeston. 80. Halswell. 81. Pigeon Bay. 82. Okain's. 83. Mueller. 84. Cass. 85. North Tekapo. 86. Fox. 87. Mount Peel. 88. Acland. 89. Shepherd Bush. 90. Westerfield. 91. Ashburton. 92. Rakaia. 93. Hurst. 94. Southbridge. 95. Ellesmere. 96. Akaroa. 97. Gough's Bay. 98. Ward. 99. Tasman. 100. Jollie. 101. Tekapo. 102. Opuha. 103. Four Peaks. 104. Orari. 105. Rangitata. 106. Hinds. 107. Wakanui. 108. South Rakaia. 109. Hopkins. 110. Pukaki West. 111. Pukaki. 112. Burke. 113. Tengawai. 114. Opihi. 115. Geraldine. 116. Kapunatiki. 117. Coldstream. 118. Campbell. 119. Strachey. 120. Gladstone. 121. Mackenzie. 122. Opawa. 123. Pareora. 124. Arowhenua. 125. Hewling. 126. Dalzeil. 127. Nimrod. 128. Otaio. 129. Patiti. 130. Gibson. 131. Hakataramea. 132. Waihao. 133. Waimate. 134. Meyer. 135. Elephant Hill. 136. Waitaki.
WESTLAND
1. Punakaiki. 2. Maimai. 3. Te Miko. 4. Waiwhero. 5. Mawheraiti. 6. Cobden. 7. Mawheranui. 8. Ahaura. 9. Pohaturoha. 10. Lewis. 11. Travers. 12. Arnold. 13. Greymouth. 14. Waimea. 15. Hohonu. 16. Brunner. 17. Kopara. 18. Haupiri. 19. Stewart. 20. Te Kinga. 21. Mahinapua. 22. Kanieri. 23. Turiwhate. 24. Otira. 25. Taramakau. 26. Clifton. 27. Waitaha. 28. Totara. 29. Toaroha. 30. Browning's Pass. 31. Arthur's Pass. 32. Mount Oneone. 33. Wanganui. 34. Mount Bonar. 35. Whitcombe's Pass. 36. Murray. 37. Okarito. 38. Wataroa. 39. Poerua. 40. Butler. 41. Gillespie's. 42. Waiho. 43. Waitangitaona. 44. Tyndall. 45. Paringa. 46. Bruce Bay. 47. Karangarua. 48. Mount Cook. 49. Otumotu. 50. Abbey Rocks. 51. Mount Douglas. 52. Mount Sefton. 53. Moorhouse. 54. Arnott. 55. Mount Munro. 56. Mount Napoleon. 57. Smoothwater. 58. Hapuka. 59. Okuru. 60. Mataketake. 61. Clarke. 62. Landsborough. 63. Barn Bay. 64. Cascade. 65. Arawata. 66. Turnbull. 67. Governor's Pass. 68. Haast Pass. 69. Awarua. 70. Gorge River. 71. Macfarlane. 72. Jackson. 73. Mount Castor. 74. Mount Aspiring.
SOUTHLAND
1. Doon. 2. Arran. 3. Eglinton. 4. Swinton. 5. Mid Wakatipu. 6. Coneburn. 7. Mavora. 8. Eyre North. 9. Esk. 10. Lyall. 11. Te Anau. 12. Snowdon. 13. Black Hill. 14. Eyreside. 15. South Wakatipu. 16. Kingston. 17. Spey. 18. Manapouri. 19. Mararoa. 20. Burwood. 21. Lincoln. 22. Eyre. 23. Nokomai. 24. Rockyside. 25. Gap. 26. Borland. 27. Titiroa. 28. Takitimo. 29. Centre Hill. 30. Garvie. 31. Wakaia. 32. Cleughearn. 33. Monowai. 34. Wairaki. 35. Taringatura. 36. Hokonui. 37. Wendonside. 38. Wendon. 39. Otama. 40. Chatton. 41. Hauroko. 42. Lillburn. 43. Waiau. 44. Wairio. 45. West Cape. 46. Preservation. 47. Hakapoua. 48. Waitutu. 49. Rowallan. 50. Alton. 51. Aparima. 52. Oreti. 53. Winton. 54. Forest Hill. 55. Waimumu. 56. Waikaka. 57. Longwood. 58. Jacob's River. 59. New River. 60. Lindhurst. 61. Tuturau. 62. Mabel. 63. Lothian. 64. Mataura. 65. Slopedown. 66. Invercargill. 67. Oteramika. 68. Wyndham. 69. Mokoreta. 70. Campbelltown. 71. Toetoes. 72. Waikawa. 73. Otara. 74. Anglem. 75. Mason. 76. Paterson. 77. Pegasus. 78. Lord's River. 79. South Cape. 80. Castlemount. 81. Glaisnock. 82. Clinton. 83. Greenstone. 84. Clintonside. 85. Von. 86. Caples. 87. Upper Wakatipu. 88. Lorn. 89. Mitre Peak. 90. Milford Sound. 91. Greenvale.
OTAGO
1. Young. 2. Haast. 3a. Hunter. 3b. Stafford. 3c. Ward. 3d. Hopkins. 3e. Campbell. 4. Mount Pollux. 5. Wilkin. 6. McKerrow. 7. Upper Wanaka. 8. Upper Hawea. 9. Longslipside. 10. Ohau Lake. 11. Ohau River. 12. Wilmot. 13. Martin's Bay. 14. Humboldtside. 15. Forbeside. 16. Cascade. 17. Matukituki. 18. Mid Wanaka 19. Mid Hawea. 20. Longslip. 21. Ahuriri. 22. Benmore. 23. 24. Hollyford. 25. Humboldt. 26. Forbes. 27. Caples. 28. Dart. 29. Earnslaw. 30. Painoon. 31. Motatapu. 32. Lower Wanaka. 33. Lower Hawea. 34. Lindis. 35. Hawkdun. 36. Gala. 37. Castlemount. 38. Greenstone. 39. Upper Wakatipu. 40. Von. 41. 42. Glenorchy. 43. Skipper's Creek. 44. Soho. 45. Knuckle Peak. 46. Cardrona. 47. Tarras. 48. Cluden. 49. St. Bathans. 50. Turnagain. 51. Otamatakau. 52. Mount Buster. 53. Kurow. 54. Domet. 55. Maruwenua. 56. Awamoko. 57. Papakaio. 58. Mid Wakatipu. 59. Shotover. 60. Kawarau. 61. Crown. 62. Cromwell. 63. Wakefield. 64. Lauder. 65. Blackstone. 66. Idaburn. 67. Naseby. 68. Kyeburn. 69. Coneburn. 70 Nevis 71 Bannockburn. 72. Leaning Rock. 73. Tiger Hill. 74. Poolburn. 75. Gimmerburn. 76. Maniototo. 77. Swinburn. 78. Kakanui. 79. Kauroo. 80. Oamaru. 81. South Wakatipu 82. Kingston. 83. Lorn. 84. Lornside. 85. Obelisk. 86. Fraserside. 87. Fraser. 88. Cairnhill. 89. Cairnside. 90. Manor. 91. Manorside. 92. Upper Taieriside. 93. Upper Taieri. 94. Rock and Pillar. 95. Highlay. 96. Waihemo. 97. Otepopo. 98. Whitecoomb. 99. Teviot. 100. Long Valley. 101. Serpentine. 102. Loganburn. 103. Strath Taieri. 104. Budle. 105. Dunback. 106. Moeraki. 107. Wart Hill. 108. Eenger. 109. Lammerlaw. 110. St. Abb's. 111. Sutton. 112. Nenthorn. 113. Hummock. 114. Hummockside. 115. Hawksbury. 116. Greenvale. 116a. Wendon. 117. Crookston. 118. Beaumont. 119. Hedgehope. 120. Lee Stream. 121. Mount Hyde. 122. Silverpeak. 123. Waikouaiti. 124. Glenkenich. 125. Rankleburn. 126. Tuapeka West. 127. Tuapeka East. 128. Waipori. 129. Maungatua. 130. West Taieri. 131. East Taieri. 132. Dunedin and East Taieri. 133. North Harbour and Blueskin. 134. Otago Peninsula. 135. Waipahi. 136. Pomahaka. 137. Waitahuna West. 138. Waitahuna East. 139. Table Hill. 140. Clarendon. 141. Waihola. 142. Otokia. 143. Kuriwao. 144. Warepa. 145. Clutha. 146. Hillend. 147. Kaitangata. 148. Tokomairiro. 149. Akatore. 150. North Tuakitoto. 151. South Tuakitoto. 152. Inch-Clutha. 153. Coast. 154. South Molyneux. 155. North Molyneux. 156. Rimu. 157. Catlins. 158. Glenomaru. 159. Woodland. 160. Tautuku. 161. Green Island West. 162. Green Island Bush. 163. Lower Kaikorai. 164. Ocean Beach. 165. Town. 166. Anderson's Bay. 167. Tomahawk. 168. Wakari. 169. Upper Kaikorai. 170. North-east Valley. 171. Upper Harbour West. 172. Upper Harbour East. 173. Sawyer's Bay. 174. Lower Harbour West. 175. Portobello Bay.

LITERATURE.

(1) BEAL, L. O.: "Otago as a Mining District." *The New Zealand Mining Handbook*, 1906, pp. 199–203.
(2) BRANCH, W. J., and DAGGER, J. R.: "The Conglomerates of the Lower Wairau Valley, Marlborough." N.Z. Jour. Sci. & Tech., Vol. 16, 1934, pp. 121–35.
(3) COTTON, C. A.: "The Tuamarina Valley: A Note on the Quaternary History of Marlborough Sounds." Trans. N.Z. Inst., Vol. 45, 1913, pp. 216–22.
(4) DON, J. R.: "The Genesis of Certain Auriferous Lodes." Trans. Am. Inst. Min. Eng., Vol. 27, 1898, pp. 564–668.
(5) DOWNEY, J. F.: "Quartz Reefs of the West Coast Mining District, New Zealand." 1928.
(6) EMMONS, W. H.: "The Principles of Economic Geology." 1918.
(7) FINLAYSON, A. M.: "Some Observations on the Schists of Central Otago." Trans. N.Z. Inst., Vol. 40, 1908, pp. 72–9.
(8) ——— "The Scheelite of Otago." *Ibid.*, pp. 110–22.
(9) ——— "The Geology of the Quartz Veins of the Otago District. *Ibid.*, Vol. 41, 1909, pp. 64–84.
(10) GANNETT, R. W.: "Experiments relating to the Enrichment of Tungsten Ores." Econ. Geol., Vol. 14, 1919, pp. 68–78.
(11) HECTOR, J.: "Reports on Gold-mines in the Province of Marlborough." Rep. Geol. Explor., 1871–72, No. 7, 1872, pp. 119–29.
(12) ——— "Report on the Golden Point Quartz Reef, Queen Charlotte Sound." *Ibid.*, 1877–78, No. 11, 1878, pp. 1–5.
(13) ——— "Endeavour Inlet Antimony Mine." *Ibid.*, 1890–91, No. 21, 1892, pp. xxix–xxx.
(14) HENDERSON, J.: "Gold-bearing Quartz Veins near Havelock, Pelorus Sound." N.Z.G.S., 24th Ann. Rep., 1930, pp. 21–22.
(15) ——— "Notes on the Geology and Mineral Occurrences of the Wakamarina Valley." N.Z. Jour. Sci. & Tech., Vol. 1, 1918, pp. 11–15.
(16) HULIN, C. D.: "Geology and Ore Deposits of the Randsberg Quadrangle, California." Cal. State Min. Bur., Bull. No. 95, 1925.
(17) MCKAY, A.: "The District between Kaituna Valley and Queen Charlotte Sound." Rep. Geol. Explor., 1878–79, No. 12, 1879, pp. 86–97.
(18) ——— "The District between the Wairau and Motueka Valleys." *Ibid.*, pp. 97–121.
(19) ——— "On the Antimony Lodes of Endeavour Inlet." *Ibid.*, 1885, No. 17, 1886, pp. 10–13.
(20) ——— "On the Mahakipawa Goldfield." *Ibid.*, 1888–89, No. 20, 1890, pp. 36–44.
(21) ——— "On the Geology of Marlborough and the Amuri District of Nelson." *Ibid.*, pp. 85–185.
(22) ——— "On the Geology of Marlborough and South-east Nelson." *Ibid.*, 1890–91, No. 21, 1892, pp. 1–28.
(23) MARSHALL, P.: "The Geology of the Tuapeka Subdivision." N.Z.G.S., Bull. No. 19, 1918.
(24) MORGAN, P. G.: "Scheelite Mines of Otago." N.Z.G.S., 14th Ann. Rep., 1920, p. 10.
(25) ——— "Picton Coal." *Ibid.*, 25th Ann. Rep., 1921, pp. 11–18.
(26) PARK, J.: "The Geology of the Cromwell Subdivision." N.Z.G.S., Bull. No. 5, 1908.
(27) ——— "The Geology of the Queenstown Subdivision." N.Z.G.S., Bull. No. 7, 1909.
(28) RICKARD, T. A.: "The Goldfields of Otago." Trans. Am. Inst. Min. Eng., Vol. 21, 1893, pp. 411–42.
(29) TURNER, F. J.: "Schists from the Forbes Range and Adjacent Country, Western Otago." Trans. R.S.N.Z., Vol. 64, 1934, pp. 161–74.
(30) ULRICH, G. H. F.: "Report on the Geology and Goldfields of Otago." 1875, pp. 155–236.
(31) WAGONER, L.: "The Detection and Estimation of small Quantities of Gold and Silver." Trans. Am. Inst. Min. Eng., Vol. 31, 1901, pp. 798–810.
(32) WILBOURN, E. S., and INGHAM, F. T.: "The Geology of the Scheelite Mine, Kramat Pulai Tin, Limited, Kinta, Federated Malay States." Q.J.G.S., Vol. 89, 1933, 449–79.
(33) WILLIAMSON, J. H.: "Quartz Lodes of Oturehua, Nenthorn, and Macraes Flat, Otago." N.Z. Jour. Sci. & Tech., Vol. 16, 1934, pp. 102–20.

METEOROLOGICAL BRANCH.

REPORT BY THE DIRECTOR, 1934–35.

General.

The most important development throughout the year has been the great actual, and still greater prospective, increase in the amount of air traffic in New Zealand. For safe flying the pilot must know the general weather obtaining along his route, and particularly that at the aerodromes at which he is to land. In the past provision has been made for this by the use of the general weather forecasts and telephoning between aerodromes. At best this is a rather inadequate method and for regular services it is quite unsatisfactory. In Europe reports of the weather along air routes are issued at least hourly, and forecasts usually once every three hours. Though so highly developed a service may not yet be justified in New Zealand, something on a similar scale is certainly required. The principal difficulty, at present, is to find adequate means of intercommunication at a reasonable cost, especially since the air services will be operating early in the morning. The best method would appear to be by the establishment of wireless telegraph, or combined telephone and telegraph stations, at the main aerodromes, in close touch with the Meteorological service. It is hoped that, in consultation with the Post and Telegraph Department and the Controller of Civil Aviation, some suitable scheme may be devised. In the meantime the staff of the Meteorological Office is to be increased so that certain officers shall be able to devote their time and attention to the requirements of aviation. The development of the best service possible under the conditions obtaining will naturally be a matter of considerable time and experience.

The greatly increased interest being given to the weather and weather forecasting must not be allowed to obscure the need for the study of our climate and the provision of data regarding it for those engaged in industry and investigations of all kinds. In the case of agriculture particularly it seems increasingly clear that, with the intense international competition which is to be expected in the future, production and methods must be adapted as closely as possible not only to the climate of the Dominion as a whole, but even to the slightest local variations. It is noticed that increasing use is being made of the publications of the Meteorological Office dealing with various aspects of the climate.

There has been a very greatly increased demand for weather forecasts during the year, especially for those issued from the stations of the Radio Broadcasting Board. The main centres, especially, have shown a keen desire for special forecasts for their own localities.

Observing Stations.

Such inspection of stations as was possible has been carried out during the year, and each tour only serves to emphasize the need for closer supervision. In almost all cases the only instruction meteorological observers in New Zealand receive is confined to printed matter and brief and rare visits of inspecting officers. A very good plan has been in vogue for some years in England whereby observers may receive a course of personal instruction at the Kew Observatory extending over a month. It would be a great advantage if a similar arrangement could be made here.

An improvement has been made at a number of telegraphic reporting stations by installing small screens for the thermometers in satisfactory exposures so that truly representative temperature readings may be obtained. The number of stations which report visibility has also been largely increased. This information will be of value to aviators.

About fifteen new rainfall stations were established, and several others were moved to more favourable positions. Five were discontinued.

One climatological station was abandoned and re-established elsewhere.

Forecasting.

Effort has been concentrated during the year on the gaining of experience and skill in the application of "frontal" methods to the analysis of weather charts, reference to which was made in the last report. Until August we continued to have the benefit of the assistance of Mr. J. Holmboe, the meteorologist of the Lincoln Ellsworth Antarctic Expedition. Considerable progress has been made, but much more work will have to be done before all the officers concerned have become fully proficient. In this connection we were unfortunate in losing the services of Mr. C. E. Palmer, who had shown a special aptitude for this method of analyses. Mr. Palmer left to take up a position at the Victoria University College.

There are many ways in which conditions here differ from those in other parts of the world, and much experience and the development of a special technique is required before local difficulties can be overcome. The lack of reports from the Tasman Sea will always be a source of trouble, especially as regards giving the precise times of weather changes. Fortunately, we shall soon be receiving much more complete reports from Australia, and this will be of very great assistance. It has already been our experience that the methods enable a much closer insight to be gained into weather processes than previously. They also make it much easier to understand and allow for the effects of local topography. An increase in the accuracy of forecasts has resulted, but it is especially for forecasts for short periods up to twelve hours that the method proves its value. These will be of especial importance in connection with aviation.

Special local forecasts are now prepared for the Auckland and Canterbury Districts and are issued nightly from the radio broadcasting stations 1YA and 3YA respectively. The afternoon forecast instituted for farmers, and also broadcasted, has proved increasingly popular.

Arrangements have been made to issue reports of the weather at various places in New Zealand and the surrounding area at 9 p.m., New Zealand time, in international code from the beginning of the coming financial year. The advantage of the international code is its brevity and the fact that similar reports are being issued in all parts of the world. It is therefore a great convenience, especially to overseas shipping. For all services it is desirable owing to the rapidly increasing volume and speed of international traffic, the dependence of aircraft on meteorological information, and the increasing congestion of the ether to approach as nearly as possible to international codes, units, and time-tables.

Upper-air Observations.

The observations of pilot balloons for the determination of winds in the upper air has been continued once daily at Wellington, and we have also received corresponding data from the Christchurch Magnetic Observatory. During the coming year it is hoped that these observations will be made more frequently, and at Auckland, as well as the other centres. The information thus obtained is intended to be made available to aviators. It will be of considerable assistance to them in estimating their ground speed and in choosing the most favourable flying height.

Publications.

Regular publications have been maintained as follows:—

(1) Monthly in the Government *Gazette*,—
Daily observations of pressure, temperature, &c., at the Kelburn Observatory, Wellington.
Notes on the weather of the Dominion for the month.
Summary of temperature observations at climatological stations other than Wellington.
Total rainfall and number of days for all rainfall stations.
Once a year, also, a table is included giving the total rainfalls, differences from average, and the greatest day's fall for all stations during the previous year.

(2) Volume of "Meteorological Observations." This contains monthly and annual means of pressure, temperature, wind, sunshine, and other climatological data from upwards of forty stations; monthly means for each hour of the day of pressure, temperature, rainfall, and sunshine at Wellington, and temperature at Alexandra; table of values of total solar radiation; and a map showing departure from normal of rainfall over the whole country for the year concerned. The 1933 number, the last issued, contained also a table of the mean amount of cloud at Wellington at each hour from early morning till late at night, the observations out of office hours having been made by Mr. A. G. C. Crust.

A paper on "Frontal Methods of Weather Analysis applied to the Australia - New Zealand Area" was prepared by the Director and Mr. J. Holmboe, and has been printed. It discusses four series of weather charts illustrating some of the main types of weather experienced in this region. The charts had been analysed by Mr. Holmboe and are the first published in the Southern Hemisphere in which the Norwegian method has been applied in such detail and by one thoroughly versed in it. The paper will therefore be valuable for reference to those interested in the meteorology of Australia and New Zealand. The last of the series of charts traces the history of a tropical cyclone and is of considerable theoretical interest.

A paper of similar type, but expressed in simpler language, was published in *The Australian Geographer*. This paper was entitled "The Analysis of Weather Charts" and dealt with the weather sequence from the 29th August to the 6th September, 1934. In this series the meteorological situation was always particularly clearly defined, and it was unusually suitable for demonstration purposes.

Miscellaneous.

The cordial co-operation of members of the staff throughout the year is gratefully acknowledged.

Attention is also drawn to the valuable and public-spirited work performed by the numerous voluntary observers in all parts of the country. Without them the securing of an adequate record of the climate of the country would be very difficult and very costly.

The Branch is indebted to the Post and Telegraph Department, particularly the Telegraph Division, for their ready and courteous assistance at all times.

Summary of the Weather for 1934.

January was a cold and stormy month. The distribution of rainfall was irregular. Most of Canterbury had very heavy rains, which did much good to crops and pastures. Nelson and Marlborough, which had been suffering from a prolonged drought, again had a very dry month. In the North Island also, apart from Taranaki and the South Taranaki Bight, the rainfall was much below average. There were numerous thunder and hail storms. The latter were responsible for much local damage to wheat crops in Canterbury. A frost on the 23rd did considerable damage to tender crops, many tobacco-plantations in the Nelson District suffering severely.

February was another cold month. Most of the North Island experienced very heavy rains, floods occurring in North Auckland, the Bay of Plenty, and Hawke's Bay. In the South Island, Nelson and Marlborough continued to experience the most severe drought on record. On the west coast the month was a particularly dry and fine one. Elsewhere, though in some parts the rainfall was low, conditions were very humid. Except in Nelson and Marlborough, there had been abundant growth of pasture, and the country was in excellent condition.

Towards the end of *March* the drought was broken in Nelson and Marlborough. In the remainder of the South Island the rainfall was erratic in distribution but generally fairly high. The North Island had very much less than usual. Temperatures remained below normal, but there was little wind. The condition of stock and pastures was still good.

April was a mild month, with an absence of strong winds. Though rainfall was below average in most districts, the atmosphere was damp and cloudy. The soil at the close of the month was generally well saturated with moisture, and the condition of stock and pastures was satisfactory. A severe frost occurred on the 13th. On the 25th the mountain-ranges received a considerable snowfall.

In *May* rainfall was below average over most of the North Island, while in most of the South, and especially Canterbury, the month was a very wet one. Temperatures were below normal, and in the South Island there was much cloudy weather. Though most of the month was quiet there were two rather severe storms. Between the 3rd and the 5th a deep cyclone moved southward from Cape Maria van Diemen across the North Island to Banks Peninsula. It caused north-easterly gales and heavy general rains. There was much flooding in the Auckland Province, and Little River (on Banks Peninsula) had a flood of catastrophic proportions. During the second storm, from the 15th to the 17th, there were very severe north-westerly gales. Southerly gales followed, and there were very widespread snow and hail storms. A tornado was experienced at New Plymouth on the 17th.

June was a rather cold and sunless month, but until the last few days there was little wind. Rainfall was, on the whole, somewhat above normal. The wet conditions interfered with farming operations in Canterbury. Stormy weather was experienced on the 27th and 28th culminating in a very cold spell, with widespread snow and hail storms.

In *July* North Auckland, Otago, and Southland, and districts about Cook Strait, had more than the average rainfall. Elsewhere there was less than usual, the deficits being particularly large in Canterbury. Temperatures were below normal. There were further heavy and extensive falls of snow on the 3rd and 4th.

Apart from two severe cold snaps, accompanied by widespread snowfalls, *August* was a mild and springlike month. Rainfall was much above the average in the South Island, but, on the whole, rather below it in the North. Stock and pastures were in good condition, but the wetness of the soil prevented the sowing of wheat crops on many farms in Canterbury.

A rather severe cold spell occurred from the 10th to the 12th of *September*, but otherwise the weather was mild and pleasant. The greater part of it was dry, but practically all parts of the country received good rains at some period. There was vigorous growth of vegetation, and the spring season was unusually far advanced. Lambing results were very good.

In *October* the first two days were cold, but after that the weather was fairly mild and equable, with less westerly wind than usual. The rainfall distribution was rather irregular, but, except in eastern districts of the North Island, there was no shortage of moisture. On the whole, October was one of the best spring months the country has experienced. There was a wonderful flush of growth of grass and vegetation.

November was a remarkable month. It was almost continuously warm and resembled a summer rather than a spring month. There was little wind, and sunshine was much above the average. It was the driest November experienced for many years, especially in the South Island.

December was even more remarkable than November. Not only was it the warmest December on record, but the average departures from normal over the country have never previously been equalled in any month. Again there was continuous warmth and an absence of wind. Many places had the greatest amount of sunshine hitherto recorded in December. North Auckland, which had had a wet month in November, also had some exceptionally heavy rains and severe floods. Almost everywhere else the month was drier even than November. Pastures became parched and brown and fruits and crops ripened prematurely. The milk-yield fell off considerably.

Year.—Rainfall was much above the average in North Auckland, but below it over almost the whole of the remainder of the North Island. In the South Island, districts which get most of their rain in winds from a westerly quarter had a dry year, but in the eastern half the totals were generally above average. On the whole, as regards rainfall, it was a better year than the preceding four.

Mean temperatures for the year were almost everywhere above normal, though departures were very slight on the east coast and in the Bay of Plenty area. In parts of the western districts and the interior of the South Island they amounted to just over 1° F. The relatively high means were, however, completely accounted for by the very high temperatures which prevailed in November and December. With the exception of April, the first seven months were cold. The warmth in April was extremely important since it ensured supplies of winter feed for stock, prospects for which, in parts of the South Island at any rate, had previously appeared very uncertain. As already indicated, the spring was mild and the growth of pasture luxurious. Stock had a good year, though at the end dairy cattle were falling away and the milk-yield decreasing. The lambing season was excellent. Crops generally were fair. The 1934–35 season was one of small numbers and large fruit so far as apples were concerned, while the wheat crop was short through the wet ground in winter preventing a certain amount of sowing. The white butterfly spread further over the South Island and was responsible for much damage.

DOMINION OBSERVATORY.

REPORT OF THE DOMINION ASTRONOMER AND SEISMOLOGIST FOR THE YEAR ENDED 31ST DECEMBER, 1934.

BUILDINGS AND EQUIPMENT.

The buildings and equipment have been kept in good order and condition. The Observatory grounds have been kept in order by the Wellington City Council.

ASTRONOMY.

Time Service.—The Observatory signal clock has been controlled mainly by the reception of radio time signals. The following radio time signals were received :—

Station.	Call Sign and Wave.	Hour (G.M.T.).	Number of Times received.	Greatest observed Error of Observatory Clock.
Nauen	DFY (LW)	00	29	1·07 seconds fast on January 16th.
Norddeich	DAN (SW)	00	36	0·58 second fast on September 17th.
Honolulu	NPM (LW)	00	91	0·66 second slow on October 14th.*
Malabar	PKX (LW)	01	13	0·53 second fast on September 6th.†
Washington.. ..	NAA (SW)	03	2	1·33 seconds slow on March 6th.‡
Zikawei	8ZW (SW)	03	75	0·29 second fast on August 23rd and September 27th.
Honolulu	NPM (SW)	03	51	0·37 second fast on September 24th.
Washington.. ..	NAA (SW)	08	107	1·08 seconds slow on March 6th.‡
Bordeaux	FYL (LW)	08	3	0·10 second slow on February 20th.
Washington.. ..	NAA (SW)	21	185	2·24 seconds slow on March 8th.‡
Washington.. ..	NSS (SW)	21	4	0·19 second slow on February 22nd.
Monte Grande ..	LSD (SW)	2350	134	0·51 second fast on April 24th.

* Large difference apparently due to error in NPM signal. † Large difference apparently due to error in PKX signal. ‡ Large difference due to earthquake of March 6th.

The total number of signals received during the year was 730. The signals received comprise both mean time and rhythmic signals from Nauen, Norddeich, Malabar, Bordeaux, and Monte Grande ; and the mean time signals only from Washington, Honolulu, Zikawei.

It is not possible to make use of the British time signals from Rugby radio, owing to the unsuitable times of transmission (5 h. 30 m. and 21 h. 30 m. N.Z.M.T.).

Time Signals sent out from the Observatory.—The time service has been maintained as previously and the regular time signals sent out. The present routine at the Observatory provides for the following time signals, most of which are sent automatically by the Observatory clock, the error of which seldom exceeds a quarter of a second of time.

Automatic signals have been sent to—

(1) The General Post Office and the Railway Department, Wellington, by telegraph daily at 9 h., except on Sundays and Government holidays.
(2) Ships and to the general public at Wellington, by electric lights at the Observatory, daily at 20 h. 30 m.
(3) The Auckland Harbour Board, by electric lights at Auckland, on Tuesdays and Fridays at 20 h. 30 m., except on Government holidays.
(4) The South Island telegraph offices, by telegraph, on Tuesdays and Fridays at 15 h. 30 m., except on Government holidays.
(5) The Lyttelton Harbour Board, by dropping the time ball at Lyttelton on Tuesdays and Fridays at 15 h. 30 m., except on Government holidays. This signal was discontinued in December by the authority of the Lyttelton Harbour Board, 13th December, 1934, in the Marine Department Notice to Mariners, No. 1 of 1935. This was also noted in the British Admiralty Notices to Mariners of 2nd March, 1935, No. 351.
(6) The Radio Broadcasting Board's station 2YA at Wellington, at 10 h. 30 m., 15 h. 30 m., and 19 h. 30 m. N.Z.M.T. (23 h., 4 h., and 8 h. G.M.T.) on week days and at 15 h. 30 m. N.Z.M.T. on Sundays. The Board's station 3YA at Christchurch rebroadcasts the signals from station 2YA. The service from 3YA commenced on April 24th.
(7) Through the Wellington Radio Station ZLW, on Tuesdays and Fridays at 20 h. 30 m. (= 9 hours G.M.T.), except on Government holidays.
(8) Through the Wellington Radio Station ZLW, daily at 10 h. 30 m. (= 23 hours G.M.T.).

In transmitting radio time signals the call sign of the Observatory from January 1st to June 30th was ZLY, but on and after July 1st the call sign was changed to ZMO in accordance with the provisions of the Madrid Radio Communication Regulations, Article 14, paragraph 2.

Non-automatic time signals are transmitted as follow :—

(1) The Observatory automatic time signals sent to the General Post Office are distributed by telegraphic hand signals to some 2,300 telegraph and telephone offices distributed all over New Zealand, at 9 h. daily.
(2) Similar hand signals are also sent to all railway offices in New Zealand at 9 h. daily—by telegraph to 221 offices, and by telephone to 257 stations.

The following list gives the number of time signals sent out during the year 1934 :—

	Number of Signals.
Radio time signals through ZLW	466
Radio time signals through 2YA	977
Radio time signals through 3YA	622
Time signals by telegraph	414
Time signals by lights at Wellington	365
Time signals by lights at Auckland	101
Time signals by time-ball at Lyttelton	96
Time signals by telephone	18
Total number of signals sent out in 1934	3,059

The following table indicates the degree of accuracy of the radio time signals sent out from the Observatory through stations ZLW and 2YA, during the year 1934 (at 10 h. 30 m. and at 20 h. 30 m. N.Z.M.T.) :—

Number of times correction did not exceed 0·25 second	442
Number of times correction between 0·26 and 0·50 second	20
Number of times correction between 0·51 and 1·00 second	4
Number of times correction exceeded 1·00 second	0
Number of time signals sent out	466

During the year 1934 there were no failures of the signals through station ZLW. On November 11th, at 11 h. (New Zealand summer time) the radio time signals between 11 h. and 11 h. 2 m. were suppressed for the observance of the Armistice Day two minutes' silence.

The radio time signals supplied to 2YA were not broadcast on three occasions. There were eleven times when the station definitely did not broadcast the signals owing to the nature of the programme, and twelve times when the signals were incomplete or faulty. On one of these latter occasions the fault was due to the contact at the Observatory. As the broadcast of time signals through stations 2YA and 3YA is controlled by the station staffs, the Observatory cannot guarantee regularity in this service.

The time signals by telephone were given to Government House, Post and Telegraph Department, and Defence Department.

Government Buildings Clock.—The Government Buildings clock has been kept under fairly close control. A record is obtained at the Observatory each day by direct circuit from the clock, and adjustments are made as required. The greatest errors of this clock were thirty-nine seconds slow on October 13th and twenty-seven seconds fast on September 28th.

General Post Office Clock.—The General Post Office clock is checked by W/T daily, at 15 h., except on Saturdays, Sundays, and Government holidays. The greatest errors observed were ten seconds slow on June 15th and seven seconds fast on March 21st and June 6th.

Summer Time.—The Summer Time Amendment Act, 1933, provided for the time in New Zealand being half an hour in advance of New Zealand mean time for the period beginning at 2 h., New Zealand mean time, on Sunday, 1934, September 30th, and ending at 2 h., New Zealand mean time, on Sunday, 1935, April 28th.

Solar Work.—Observations of sunspots were continued during the year by Mr. Thomsen with the 5 in. Grubb refractor belonging to the Astronomical Section of the Wellington Philosophical Society. The results have been sent regularly to Zurich, according to arrangements with the International Astronomical Union. New Zealand is considered by the authorities to be a very valuable station for this work on account of its geographical position.

Observations were made on 103 days. There were thirty-seven days when no spots were visible, and altogether records and measurements were made of 102 centres of activity. Nearly all of the spots had a high heliographic latitude, showing that the new solar cycle was well established. The most notable sunspot was one which crossed the central meridian of the sun on April 22. It had an umbral diameter of 17,000 miles and a penumbral diameter of 28,300 miles. The area in millionths of the sun's hemisphere was 472. On April 28th, when the spot was on the western limb of the sun observations with the 9 in. telescope of the Wellington City Observatory and the solar spectroscope, in the *c*-line of hydrogen showed a small but very active form of prominence.

Owing to many other routine duties it was not possible to make full use of the Evershed solar spectroscope on the 9 in. refractor. However, the spectroscope was calibrated for the more prominent solar lines, and observations made of prominences on April 28th and August 10th. That on August 10th was a very large one and was studied very fully at other observatories possessing spectroheliographs.

Occultations.—The programme of observing occultations at Wellington with the 9 in. telescope of the Wellington City Observatory by the Dominion Observatory staff, and with the 6 in. telescope at New Plymouth by the local astronomical society, has been continued. The Observatory is indebted in this work to the voluntary assistance by members of the New Zealand Astronomical Society, Inc., and also to the predictions in the *Handbook of the British Astronomical Association.* During 1934 conditions were not very good for this work, and therefore the number of observations is not as great as in former years. Observations were made at Wellington on August 19th and May 23rd. Observations were made at New Plymouth on February 9th and September 15th. The details of the observations have been forwarded to Dr. L. J. Comrie, Superintendent of H.M. Nautical Almanac Office, London.

Astronomical Discoveries.—By courtesy of the Central Bureau at Copenhagen, arrangements have been made for this Observatory to receive advice of all important astronomical discoveries. The information is forwarded by the Bureau through the Melbourne Observatory. In this way information was received of the discovery of a comet by Jackson at Johannesburg on March 27th. This object was much too faint for observation in New Zealand.

Longitude Work.—The reductions of the observations taken in 1933, October and November, during the International Longitude Programme are still a long way in arrears owing to the small staff at the Observatory. It is desirable that additional staff be obtained so that this important work can be completed as soon as possible.

Property on Loan.—The 4 in. altazimuth refractor, which was lent to Mr. F. M. Bateson in 1933, was returned to the observatory in good condition. The 5 in. altazimuth refractor is still on loan to Mr. M. Geddes, of Otekura. This instrument is being used very well by Mr. Geddes. The conditions of loan for instruments are that they must be periodically returned to the Observatory for inspection, and that the borrowers must insure them against loss by fire or damage, and make regular reports of the use made of telescopes.

Two chronometers have been lent to observers to check the times on the seismographs. One of them is lent to Mr. H. de Denne, Hastings, and the other to Mr. L Bastings, Dannevirke.

Improved Time Service.—It is hoped that more time signals can be sent out daily to allow more accurate checking of the time recorded on the seisomographs. With the increased number of seismographs now in operation more frequent time checks are necessary if the best results are to be obtained.

Seismology.

General.—Seismic activity in New Zealand was higher in 1934 than in 1933. The most important earthquake was that which occurred on 5th March, at 11.16 p.m., N.Z.M.T. It reached R.F. 9 in parts of northern Wairarapa, and chimneys fell over a wide area in the southern part of the North Island.

Seismograph Stations.—During the year 1934, continuous seismograph records were kept at the Dominion Observatory, Wellington, the Magnetic Observatory, Christchurch, and at the following subsidiary stations: Arapuni, Tuai, New Plymouth, Hastings, Bunnythorpe, Takaka, Greymouth, and Chatham Islands. In October a Milne-Jaggar seismograph was installed at East Cape Lighthouse and placed in charge of Mr. H. Jamieson, Principal Keeper. In October a Milne-Jaggar was also established at the Observatory, Stratford, in charge of Mr. A. W. Burrell.

On account of the difficulties of maintaining a satisfactory time service at the Suva Seismograph Station, arrangements were made with the Government of Fiji for the station to be closed and the Milne Twin-boom seismograph to be lent to this Observatory. The Suva seismograph ceased recording at the end of July, and the machine was sent to New Zealand. It is hoped shortly to adapt it for use in this country. The records of the Wood-Anderson seismograph, belonging to this Observatory and installed at the Magnetic Observatory, Christchurch, have been regularly forwarded for measurement.

Two seismograph stations, which are privately owned, take part in the seismological service, the the observers supplying this Observatory with records and reports. The Observatory is grateful to these observers for their voluntary services, and also to the officers of other Government Departments and private individuals who operate seismographs.

The following is a complete list of seismograph stations which were operating in New Zealand and the surrounding islands on 31st December, 1934:—

Station.	Position.		Instruments.	Observer.
	Latitude.	Longitude.		
	° ′	° ′		
Apia	13 48 S.	171 47 W.	Wiechert, three components ..	The Director, Apia Observatory.
*East Cape ..	37 40 S.	178 35 E.	Milne-Jaggar	Mr. H. B. Jamieson, Marine Department.
Arapuni ..	38 5 S.	175 39 E.	Milne, E.–W. component ..	Mr. C. A. Thompson, Powerhouse Superintendent, Public Works Department.
Tuai	38 48 S.	177 9 E.	Milne-Jaggar	Mr. W. H. Gregory, Resident Electrical Engineer, Public Works Department.
New Plymouth ..	39 4 S.	174 4 E.	(*a*) Wood-Anderson	Superintendent, H.M. Prisons.
			(*b*) Milne-Jaggar	Mr. C. E. Morshead.
*Stratford ..	39 21 S.	174 17 E.	Milne-Jaggar	Mr. A. W. Burrell.
Hastings ..	39 38 S.	176 53 E.	Milne-Jaggar	Mr. H. de Denne.
†Dannevirke ..	40 12 S.	176 7 E.	Milne-Jaggar	Dr. L. Bastings.
Bunnythorpe ..	40 17 S.	175 36 E.	Milne-Jaggar	Mr. W. A. Waters.
Takaka ..	40 51 S.	172 48 E.	Imamura, three components ..	Mr. W. J. Smith.
Wellington ..	41 17 S.	174 46 E.	Wood-Anderson, N.–S.	The Dominion Seismologist.
			Galitzin-Wilip, vertical ..	
			Milne-Shaw, Two components ..	
			Milne-Jaggar, E.–W.	
Greymouth ..	42 25 S.	171 13 E.	Milne-Jaggar	Mr. R. T. Smith, Acting District Engineer.
†Glenmuick ..	42 54 S.	173 9 E.	Inverted Pendulum	Mr. C. J. Westland.
Christchurch ..	43 32 S.	172 37 E.	Wood-Anderson	The Director, Magnetic Observatory.
			Galitzin, three components ..	
Chatham Islands	43 57 S.	176 31 W.	Milne	Mr. A. E. Haywood, Post and Telegraph Department.

* Established in October, 1934. † Privately-owned stations.

The following table gives the number of earthquakes recorded at this Observatory and the subsidiary stations during the year 1934 :—

Station.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Suva	5	4	17	24	5	12	32	..	..	..	..	..	99
East Cape	..	..	..	..	..	..	..	..	..	0	0	0	0
Arapuni	4	9	12	3	5	5	19	6	6	4	8	10	91
Tuai	1	0	9	0	0	0	1	0	0	1	1	1	14
New Plymouth	8	8	14	23	18	11	4	10	10	11	12	10	139
Stratford	..	..	..	..	..	..	..	..	..	0	0	0	0
Hastings	8	0	19	3	6	7	2	3	0	6	5	1	60
Bunnythorpe	0	1	26	3	4	2	0	1	2	1	2	1	43
Takaka	3	0	7	1	4	2	2	0	0	1	0	1	21
Wellington	36	33	119	64	48	44	75	51	51	56	58	56	691
Greymouth	0	0	1	0	0	0	1	0	0	0	0	0	2
Christchurch	3	9	13	9	8	9	11	6	8	14	13	9	112
Chatham Islands	0	0	6	4	1	2	6	1	1	0	2	2	25

Reference to the list of seismograph stations will show that the instruments are of widely varying sensitivity. Wellington is provided with a range of instruments capable of recording not only weak local shocks, but also all the main earthquakes occurring in other parts of the world. This fact accounts for the relatively large number of shocks recorded at Wellington. The figures for Christchurch are from the Wood-Anderson seismograph only, and therefore do not represent the total number of earthquakes recorded at that station.

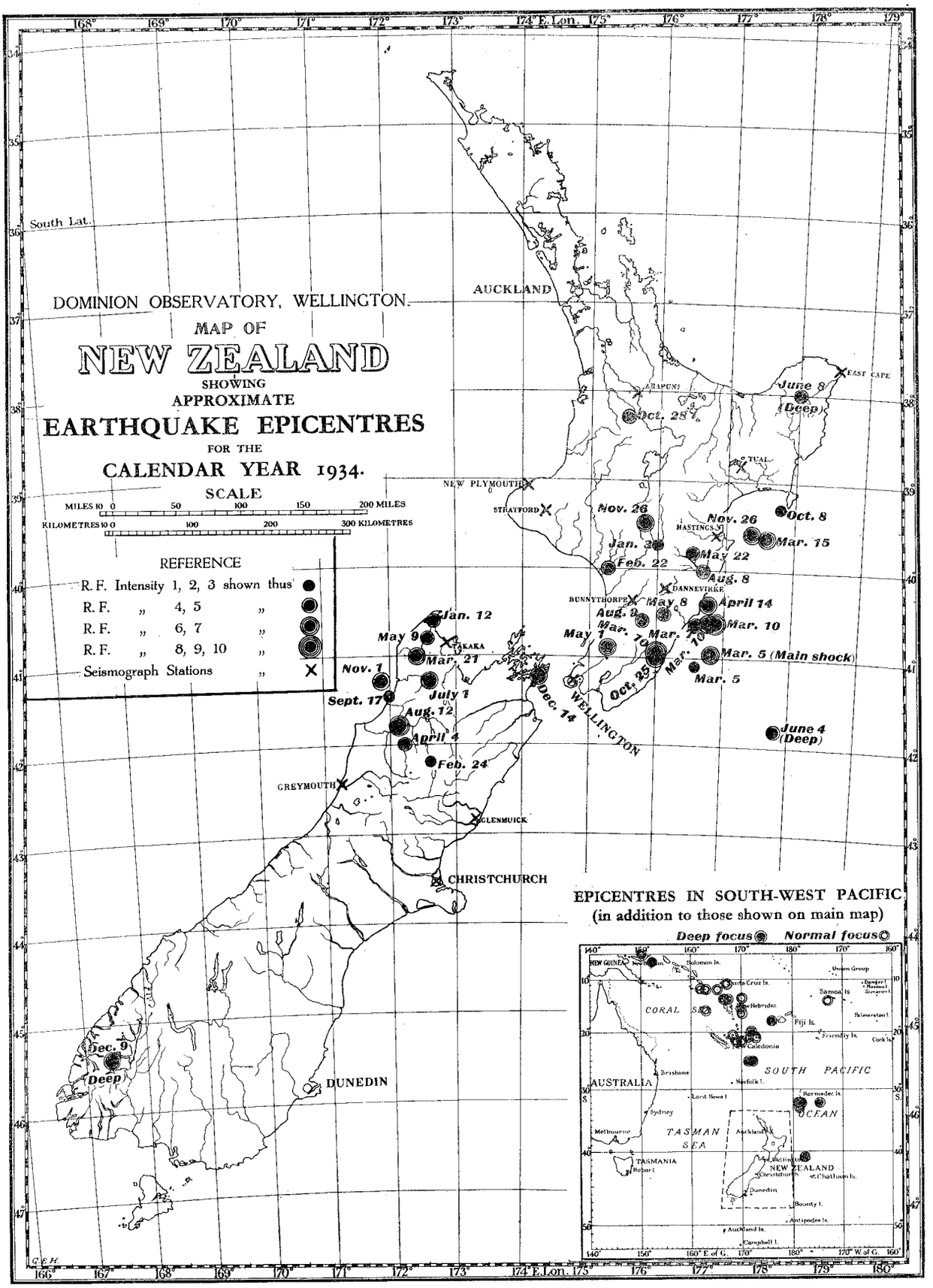
Non-instrumental Reporting Stations.—Officers of the Post and Telegraph Department and of the Marine Department, and private observers, have continued to furnish valuable reports concerning the effects of earthquakes as felt in various parts of New Zealand. The non-instrumental reports are of great assistance in the study of earthquakes. The following summary includes all earthquakes reported felt in New Zealand in the year 1934 :—

Month.	Number of Earthquakes reported felt.				Maximum Intensity (R.F. Scale).	Locality of Maximum Intensity.
	North Island.	South Island.	Both Islands.	Total for New Zealand.		
1934.						
January	5	6	0	11	5	Napier and Takaka.
February	11	5	0	16	5	Taupo and Nightcaps.
March	40	10	4	46	9	South-east part of North Island.
April	9	5	0	14	6	Castlepoint.
May	16	10	1	25	5–6	Masterton.
June	16	5	1	20	4	Many places.
July	14	5	1	18	6	Collingwood.
August	13	4	1	16	6	Murchison.
September	8	6	0	14	4	Karamea and Murchison.
October	14	4	1	17	6–7	Wanganui.
November	11	5	0	16	6	Napier and Waipawa.
December	13	7	3	17	6	Napier, Cook Strait, and Otago.
Totals	170	72	12	230	9	South-east part of North Island.

It will be seen that 230 earthquakes were felt in some part of New Zealand in the year 1934. Of these earthquakes 170 were felt in some part of the North Island, and 72 in some part of the South Island. Twelve were felt in both islands.

The following table gives the number of earthquakes in the year 1934 in which the maximum intensity reported reached various degrees of intensity on the Rossi-Forel scale :—

Month.	Rossi-Forel Scale.										Totals.
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	
1934.											
January	1	2	4	2	2	..	..	..	..	..	11
February	..	2	6	5	3	..	..	..	..	..	16
March	1	7	21	7	3	2	3	1	1	..	46
April	..	2	5	5	1	1	..	..	..	..	14
May	1	4	8	7	4	1	..	..	..	..	25
June	1	2	5	11	1	..	..	..	..	..	20
July	..	5	6	4	2	1	..	..	..	..	18
August	..	1	4	8	2	1	..	..	..	..	16
September	..	3	8	3	..	..	..	..	..	..	14
October	..	2	5	6	3	1	..	..	..	..	17
November	..	4	5	5	..	2	..	..	..	..	16
December	..	5	6	2	1	3	..	..	..	..	17
Totals	4	39	83	65	22	12	3	1	1	..	230



[*To face page 104.*

The total number of earthquakes reported felt, and the maximum intensities reported in each of the years 1921 to 1934 (inclusive), are as follows :—

Year.	Number of Earthquakes reported felt.	Maximum Intensity, R.-F. Scale.
1921	91	8
1922	1,187	8
1923	76	6
1924	70	7
1925	76	8
1926	173	8
1927	107	8
1928	80	8
1929	678	10
1930	748	8
1931	432	10
1932	313	9
1933	108	7
1934	230	9

The figures given in the above table of reported shocks require careful interpretation. In a year of major earthquakes, followed by numerous aftershocks, many of the latter pass unnoticed, while during a period of quiescence there is a tendency for all shocks, however slight, to be reported. This leads to undue emphasis being placed upon the earthquake activity of what is a comparatively quiet period. The great number of earthquakes reported in 1922 is due largely to the swarm of local earthquakes which occurred in the Taupo region in the latter half of that year.

Earthquakes in 1934.—The following is a list, giving the position of the epicentres, of all important New Zealand earthquakes in the year 1934. The list includes (1) earthquakes of high intensity, (2) earthquakes felt over a wide area :—

New Zealand Mean Time.	Approximate Position of Epicentre.		Maximum R.-F. Intensity as felt.	Places reporting Maximum Intensity.
	South Lat.	East Long.		
1934. d. h. m.	°	°		
Mar. 5 23 16	40·95	176·8	9	South-east part of North Island.
,, 5 23 27	41·1	176·6	3	Masterton and Paraparaumu.
,, 7 0 23	40·6	176·6	5	South-east part of North Island.
,, 10 6 55	..	..	5–6	Awarua Radio.*
,, 10 19 27	40·9	176·0	8	Porangahau.
,, 10 19 34	40·6	176·9	6–7	Porangahau.
,, 10 20 24	40·6	176·8	6–7	Porangahau.
,, 15 22 16	39·65	177·6	7	Northern Hawke's Bay.
,, 21 21 25	41·0	172·4	6	Takaka.
April 14 20 18	40·4	176·8	6	Castlepoint.
May 1 21 11	40·9	175·3	5–6	Masterton.
,, 8 6 4	40·5	176·1	5	Dannevirke.
,, 9 15 15	40·8	172·5	5	Collingwood and Havelock.
,, 22 16 50	38·8	176·5	5	Taupo and Rakauroa.
July 1 20 37	41·3	172·5	6	Collingwood.
Aug. 8 11 35	40·0	176·7	5	Pahiatua.
,, 9 8 0	40·6	175·8	5	Masterton.
,, 12 1 50	41·8	172·1	6	Murchison.
Oct. 25 22 35	41	176	6–7	Wanganui.
,, 28 21 16	38·3	175·5	4–5	Taumarunui.
Nov. 26 11 42	39·5	175·8	6	Waipawa.
,, 26 20 3	39·6	177·4	6	Napier.
Dec. 9 8 22	45·4	167·4	6	South Otago.
,, 14 19 44	41·3	174·2	6	Paraparaumu and Martinborough.

* This earthquake was widely felt in the southern part of the South Island, but was not sufficiently well recorded on seismographs to enable the position of the epicentre to be determined.

The approximate positions of all the earthquake epicentres which were determined in New Zealand and in the South-west Pacific generally during 1934 are shown on the accompanying map.

Survey of East Coast.—Owing to the increased seismic activity off the east coast of the North Island, and other changes which have recently been reported along the coast, it is strongly recommended that a detailed marine survey be carried out of the whole east coast, including soundings in the seas east of New Zealand.

It is probable that reliable contours of the ocean-floor will have an important bearing on the solution of geophysical problems in the New Zealand region.

Publications.

The Observatory has continued to publish a preliminary earthquake report each month, giving sufficient data for the determination of the epicentres of the principal earthquakes. These reports also include errors of the time signals sent from the Dominion Observatory. With this report is also published a preliminary seismological report from the Magnetic Observatory, Christchurch.

Besides the preliminary reports, the following complete seismological reports were published during the year 1934 :—

E. 32.—Seismological Reports for 1932, January, February, March.
E. 33.—Seismological Reports for 1932, April, May, June.
E. 34.—Seismological Reports for 1932, July, August, September.
E. 35.—Seismological Reports for 1932, October, November, December.

Also the following bulletins :—

Bulletin No. 91.—Report of the Dominion Astronomer and Seismologist for 1932.
Bulletin No. 92.—Earthquakes : The Futility of Predicting them. (R. W. de Montalk.) (Reprint from Bulletin of the Seismological Society of America, Vol. 24, No. 2, April, 1934.)

In addition, the following reprint from *The Dominion*, 1934, May 16th—
Shear Waves through the Earth's Core. (L. Bastings, M.Sc., F.Inst.P.)

An article on the Dominion time-service arrangements giving full particulars of all the time signals supplied by the Observatory, was prepared for and published in the *New Zealand Nautical Almanac*.

Articles on seismology and on mean time and time service were prepared for and published in the "New Zealand Official Year-book."

C. E. Adams,
Dominion Astronomer and Seismologist.

APIA OBSERVATORY, SAMOA.

Director: J. WADSWORTH, M.A. (Cantab.).

The same programme of work in geophysical subjects was followed during the year 1934–35 as in the past, the principal subjects of study being terrestrial magnetism, seismology, meteorology, and atmospheric electricity.

TERRESTRIAL MAGNETISM.

The work in terrestrial magnetism comprises absolute measurements and continuous records of the elements of the earth's field. The former were made with a Tesdorpf magnetometer and a Schulze earth inductor, while the latter were made with Eschenhagen variometers and a Godhavn balance. The results are tabulated in the form of hourly values of horizontal intensity, declination, and vertical force. The variometer for horizontal force was accidentally disturbed in July during an experiment which was carried out to test the coefficient of temperature. Till then its scale value at the base line was 1·47γ per millimeter, but subsequently it was adjusted to be 1·08γ.

The Godhavn balance was set up *de novo* in June, 1934. The north pole of its needle was set towards magnetic south-east and the resulting scale value was 1·05γ per minute of arc. Its records are satisfactory, except that the trace of the spot of light from the movable mirror is very faint.

The mean values of the magnetic elements during 1934 are as follows:—

Declination	10° 42·2′ east, from autographic records.
Horizontal force	35049γ, from autographic records.
Inclination (or dip)	30° 22·4′, from 27 absolute readings.

SEISMOLOGY.

The instruments used for seismological work at Apia are the 1,000 kilogram astatic pendulum and the 80 kilogram vertical seismograph designed by Wiechert. The number of earthquakes recorded during the year ending on March 31st, 1935, was 176. About 15 of them were slight local shocks which could be felt by ordinary residents, while the majority of the remainder were insignificant tremors. The earthquakes recorded on July 18th, 1934, were probably the disturbances which took place in Panama and the Santa Cruz Islands.

The vertical seismograph is very insensitive, and latterly it has not been used.

METEOROLOGY.

Meteorological work includes surface observations twice a day and some measurements of the upper winds from time to time using pilot balloons. Since January 1st, 1935, the times of the daily observations have been 9 a.m. and 3 p.m. Zone time (165 degrees west). The method used with pilot balloons has been normally the method known as the single theodolite. During the year ending on March 31st, 1935, the number of pilot balloon ascents was 63 and the greatest height reached was 37,500 ft. Measurements of the duration of bright sunshine with the Fuess recorder were resumed in September, 1934, on the arrival of a new glass ball from Germany.

Rainfall reports are being received from a new station at Lotofanga, on the south coast of Upolu, which we owe to the good offices of the Roman Catholic Mission. The number of local rainfall stations in Samoa is now about 19.

The synoptic weather reports of the South Pacific were discussed in a meeting which took place on July 2nd, 1934, on board H.M.S. "Dunedin," at Apia. It was finally decided to use the code of Copenhagen, 1929, in the form known as "weather shipping," and a regional system was recommended in which the central stations are Suva, Apia, and Papeete. These changes came into effect on January 1st, 1935.

The Officer Commanding H.M.S. "Laburnum" kindly inspected the meteorological stations at Atafu and Fakaofo during a cruise to the Tokelau Islands in June, 1934, and took a barograph back to Atafu which had been sent to Samoa for repair.

METEOROLOGICAL SUMMARY, 1934.

Month.	Pressure.	Temperature.	Rainfall.	Humidity (9 a.m.).	Sunshine.*	Wind.
	In.	°F.	In.	Per Cent.	Hours.	Miles per Hour.
January	29·794	79·4	15·25	80	144·1	5·1
February	29·827	79·4	11·54	81	..	3·6
March	29·776	78·6	20·03	84	..	4·0
April	29·824	78·7	7·42	79	..	3·8
May	29·851	79·0	6·09	81	..	4·9
June	29·865	78·7	1·64	78	..	7·5
July	29·859	78·3	7·74	81	..	6·9
August	29·892	78·1	1·10	73	..	9·4
September	29·872	78·7	10·41	77	225·4	7·0
October	29·873	78·9	4·90	75	243·6	6·9
November	29·806	79·4	14·05	79	188·8	7·7
December	29·742	79·4	20·05	81	171·5	6·6
Total	..	..	120·22	..	..	..
Mean	29·832	78·88	..	79	..	6·1

* No readings from February to August. Glass ball lost.

Notes on Tropical Storms and other Disturbances, 1934–35.

December 27th, 1934: Cyclone of moderate intensity in Tonga. Barometer 29·24 in. at Keppel Island.

January 22nd, 1935: Tropical cyclone in the New Hebrides.

February, 1935: Tropical cyclone near Rarotonga during the second week.

March 20th, 1935: A cyclone moved across the Tonga Islands.

Atmospheric Electricity.

A continuous record of the gradient of potential in the air was obtained from a Benndorf self-recording electrometer at the Land Station. Absolute measurements of the gradient were made in October using the method of the stretched wire.

Monthly Mean Values of Atmospheric Potential Gradient, Apia Observatory, Samoa, 1934.

(The units are volts per metre.)

Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
97	120	114	131	112	121	128	117	119	115	121	111	117

Tides.

A tide-gauge was maintained at the Lagoon Station, giving continuous records of the depth of water there. Tabulations of hourly values and of times and depths of high and low water were sent to the United States Coast and Geodetic Survey, Washington, D.C., U.S.A.

Time Service.

The standard clock, Strasser and Rohde No. 381, was controlled from time to time by wireless time signals from Annapolis, U.S.A., and later, when the wireless set had failed, by transit observations with the Heyde transit telescope. The "Synchronome" clock provided time signals for the magnetographs and seismographs, using current from groups of dry cells.

MAGNETIC OBSERVATORY, CHRISTCHURCH.

Director: H. F. Skey.

SUMMARY OF OPERATIONS IN 1934.

During this year the usual magnetic, seismological, and meteorological observations have been carried out.

Terrestrial Magnetism.

The Eschenhagen magnetographs at Amberley Sub-station have been kept recording continuously, and the resulting magnetograms have been developed, &c., and measured for mean ordinates during every Greenwich hour. The ordinates have been reduced and, by the aid of twice-monthly absolute magnetic observations at the sub-station, the mean hourly values have been calculated. Any short occasional failure of the Eschenhagen records has been made good by the help of the Adie D and H magnetograms obtained at Christchurch.

Calculated from these mean hourly values, the mean monthly values obtained for 1934, Amberley, are :—

Mean Monthly Values of the magnetic elements from hourly mean values (all days), 1934, at Amberley Sub-station—

1934.	D. ° ′	H.	Z.
January	18 1·6	22341γ	−55228γ
February	18 2·2	22336	55227
March	18 2·0	22329	55230
April	18 2·2	22332	55234
May	18 2·4	22331	55232
June	18 2·8	22333	55226
July	18 3·2	22336	55225
August	18 2·9	22324	55234
September	18 3·4	22323	55234
October	18 4·3	22330	55238
November	18 4·2	22335	55225
December	18 4·3	22327	55223
Year	18 3·0	22331	55230
△ from 1933	+2·8	−8γ	+3γ (Numerical decrease).

	Y.	X.	T.	ϕ
Year	06919·1γ	21232·6γ	59573·6γ	−67° 59′·97
△ from 1933	+14·9γ	−12·9γ	+4·4γ	−0′·34

Since 1930 sun-spottedness has been near the minimum, and the actual minimum has been nearly at the end of 1933. Both in H and in D the change per calendar year here has been almost uniform.

Some improvements have been effected at the Amberley Sub-station, and some necessary repairs to buildings have been made. Some further improvements to the underground chamber there are contemplated to enable the Adies to be housed in it, and leave the cellar at Christchurch available for the Galitzin and Wood-Anderson Seismographs.

Seismology.

During the year the three-component Galitzin seismographs were maintained in operation under a periodic adjustment. Provisional monthly bulletins were issued promptly. These bulletins were sent to the Dominion Observatory, Wellington, and, with their similar bulletins, went to co-operating stations overseas. Records of 240 seismic disturbances throughout the world were interpreted for these bulletins.

Apart from the prgramme of teleseismic operations by the Galitzin seismographs belonging to this Observatory, a short-period Wood-Anderson seismometer was maintained and operated for the Dominion Observatory. The Wood-Anderson records were sent regularly to the Dominion Observatory. The Wood-Anderson records are particularly valuable for shocks local to New Zealand, and the South Island in particular. After the issue of bulletins the records were returned to Christchurch and filed for reference. If a Benioff vertical seismograph, with both short and long period galvanometer, were available, facilities for local and teleseismic research would be greatly increased, as advised by Dr. Gutenberg, of Pasadena.

Meteorology.

The usual thrice-daily (Sundays and holidays, twice-daily) observations have been made, and returns made monthly to the Dominion Meteorologist. Daily information is given by telegraph of the ordinary and of the pilot-balloon observations, for use in forecasting. A careful evaluation of the semi-diurnal range of barometric pressure during 1933 is nearing completion, and as the barograph is run in a cellar without any appreciable change of temperature the ranges obtained should be accurate and of use for Polar Year discussions.

Measurements of the daily thermograms since July, 1932, have been made, and the tabulated data is to be typed for printing immediately.

Atmospheric Electricity.

The Benndorp electrograph is kept in continuous operation, but with so much work in hand difficulty is experienced in keeping measurements up to date, and it may be necessary to confine measurements in future to selected least disturbed days.

Approximate Cost of Paper.—Preparation, not given; printing (940 copies), £127 10s.

By Authority: G. H. Loney, Government Printer, Wellington.—1935.

Price 2s.]