1916.
NEW ZEALAND.

MINES DEPARTMENT.

GEOLOGICAL SURVEY BRANCH

(TENTH ANNUAL REPORT (NEW SERIES) OF THE).

Laid on the Table of the House of Representatives by Leave.

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LETTER OF TRANSMITTAL.

SIR,— Geological Survey Office, Wellington, 31st May, 1916.

I have the honour to forward herewith the tenth annual report of the Geological Survey Branch of the Mines Department. This report covers the work of the Geological Survey during the twelve months ending to-day.

I have, &c.,

P. G. MORGAN,

Director, New Zealand Geological Survey.

The Hon. W. D. S. MacDonald, Minister of Mines, Wellington.

DIRECTOR'S REPORT.

SUMMARY OF FIELD OPERATIONS.

DURING the field-season ending 31st May, 1916, the detailed surveys of the Egmont and Gisborne subdivisions were brought to a conclusion, and a re-examination of the greater part of the Whatatutu Subdivision was made. Special arrangements were made with Professors James Park and P. Marshall, of Otago University, to make surveys of the Oamaru and Tuapeka districts. These have been completed, and thus the area examined in detail during the 1915–16 season (excluding Whatatutu Subdivision) is fully 1,000 square miles. Since the reorganization of the Geological Survey in 1905 about 9,800 square miles has been subjected to detailed examination and mapping. Reports on the four districts mentioned above are now in course of preparation. Brief visits, involving geological examinations, were made by the Director to Waihi, Kaipara Harbour district, Huiroa (Taranaki), Huntly, Marlborough (coastal region), North Canterbury, and Oamaru. He also visited Trentham and the new Featherston camp at the request of the Defence Department in order to report upon soil and drainage conditions. Dr. J. Henderson made visits to Huntly, Manawatu Gorge, Mauriceville, Reefton, and Wangapeka. The chief results of these examinations are given in the special reports published on later pages.

Egmont Subdivision.

Field-work in the Egmont Subdivision was resumed by Mr. W. Gibson, Assistant Geologist, in September, 1915, and carried on until the completion of the survey towards the end of May, 1916. Mr. Gibson was assisted for some months by Messrs. L. Grange and H. A. Ellis, of the Otago School of Mines, whilst during portions of February, March, April, and May the Director also took part in the field-work. The ground examined during the past two seasons consists of the survey districts of Ngatimaru, Huiroa, Egmont, Wairau, and Cape, together with a small portion of Opunake Survey District. The total area surveyed is, roughly, 625 square miles.

Gisborne and Whatatutu Subdivisions.

Mr. M. Ongley, Assistant Geologist, recommenced work in the Gisborne Subdivision during September, 1915, and early in March, 1916, was joined by Dr. Henderson, Mining Geologist. The survey of the subdivision was completed before the end of March, and attention was then directed to a revision of the geology of the adjoining Whatatutu Subdivision, a report on which had been published in 1910 (N.Z.G.S. Bulletin No. 9). The desirability of such a revision has been felt for some years, but the field-work done in the neighbouring area by Dr. Henderson and Mr. Ongley has served to emphasize its necessity as a corollary to the report on the Gisborne area now in preparation.

Tuapeka District.

On the 1st November, 1915, Dr. P. Marshall, with the assistance of Mr. G. E. Hyde, began a detailed survey of the Lawrence, Waitahuna, and Waipori districts. Field-work was completed during February, and since then Dr. Marshall has been occupied in laboratory-work in connection with the survey and in preparing a report and maps.

Oamaru District.

Professor Park began work in the Oamaru district early in December, 1915, and remained in the field until the 7th March, 1916. Geological maps and sections have since been received from Professor Park, who also advises that his report will be forwarded at an early date.

Limestone and Phosphate Deposits.

Largely in response to requests from the Agricultural Department, a good deal of attention has been given during the past year to the limestone and phosphate deposits of the Dominion. A visit was made to the Kaipara district principally for the purpose of re-discovering a phosphate deposit from which a sample was collected many years ago by Mr. S. H. Cox, then a member of the Geological Survey staff. This was stated to come from the Hoteo River, but a search of the country near the mouth of that stream on the line of Mr. Cox's route in 1879–80 showed that no phosphate deposit of any importance could well exist in that locality. It is possible that the sample was wrongly labelled, and therefore that its source must be sought in some other locality.

A definite though thin phosphatic horizon was identified at Kaikoura and Amuri Bluff, between the "Amuri" limestone proper and an upper limestone.* Since analyses show the presence of 43·46 and 53·62 per cent. of phosphate of lime further exploration of the Marlborough coastal district is advisable. There is reason for believing that the same phosphate horizon exists in the neighbourhood of Port Robinson and in the Clarence Valley,† and it is also found in North Canterbury, though here the prospect of a commercial development is very slight.

Special visits were made by members of the staff to Douglas (Taranaki), Manawatu Gorge, Mauriceville, Cape Campbell, Ward, and Waikari in order to examine limestone deposits considered suitable for agricultural purposes. Particulars of the data obtained will be found in the reports on later pages. Attention may be drawn to the soft limestone deposits near Cape Campbell, Ward, and Waikari, which it is hoped will furnish naturally comminuted limestone of sufficiently good quality to be useful to farmers at some distance as well as to those in the immediate vicinity.

Palæontological Work.

During the past year Mr. H. Suter, of Christchurch, Consulting Palæontologist, has been steadily employed in identifying or describing the Tertiary Mollusca contained in the Geological Survey collections, and in dealing with fresh material supplied by Professor Park, Professor Marshall, officers of the Survey, and others. He has supplied a valuable report, entitled "Descriptions of New Tertiary Mollusca occurring in New Zealand, accompanied by a few Notes on necessary Changes in Nomenclature: Part I." This has been forwarded to the printer, and will be published as one of the series of palæontological bulletins.

For some months prior to his joining the Expeditionary Forces Mr. F. K. Broadgate, M.Sc., was employed in classifying the fossils at present stored in the Museum, and in allied work.

Mr. C. T. Trechmann, of Castle Eden, County Durham, England, who visited New Zealand in 1914, some months ago was again a visitor with the object of collecting Mesozoic fossils. A considerable number of Mesozoic fossils from the Geological Survey collections have been loaned to Mr. Trechmann, who has undertaken to identify and, so far as necessary, to describe them, or in special cases to arrange for this work being done by other competent palæontologists.

Publications.

During the past year the following Geological Survey publications have been issued:—

- Ninth Annual Report (as part of parliamentary paper C.-2, and in separates).
- Eighth Annual Report (second edition).
- Bulletin No. 17 (N.S.): "The Geology and Mineral Resources of the Buller-Mokihinui Subdivision," by P. G. Morgan and J. A. Bartrum.
- Palæontological Bulletin, No. 3: "Revision of the Tertiary Mollusca of New Zealand, based on Type Material, Part II," by Henry Suter.
- "Alphabetical Hand-list of New Zealand Tertiary Mollusca," by Henry Suter.

Office and Miscellaneous Indoor Work.

During the year numerous requests for information concerning New Zealand minerals and ore deposits have been answered by the Director and other members of the staff. Many mineral and rock specimens sent from all parts of New Zealand have been examined and identified. A good deal of attention has been given to the library, but owing to want of space the books cannot be satisfactorily classified.

Maps, &c.—Mr. G. E. Harris, Draughtsman, during the year compiled six maps and plans and coloured sixteen proofs of maps for the Reefton Bulletin (No. 18), drew four maps of survey districts in the Egmont and Gisborne subdivisions, two key-maps of survey districts in the Oamaru and Tuapeka districts, two geological maps and a sheet of sections for Professor Park's report on the Oamaru district, maps of Kaikoura and Huntly districts for the present report, and a small map of New Zealand. In addition to his other duties, he also attended to a considerable amount of miscellaneous office-work.

Staff.

There have been no changes in the permanent staff during the year. Mr. H. S. Whitehorn, Assistant Topographer, who in October, 1914, joined the Expeditionary Forces with the rank of captain, remains on active service, and has recently obtained his majority. Mr. F. Fulton-Wood, chainman, after serving from the outbreak of war in Samoa and the Dardanelles, returned severely wounded in November, 1915, but was able to resume office duties towards the end of December. Mr. F. K. Broadgate, temporary assistant in palæontologist work, joined the Expeditionary Forces at the end of August, 1915. Ex-members of the staff who have joined the colours are Dr. J. M. Bell, Messrs. H. Richardson, E. J. H. Webb (accidentally killed on shipboard), John Thompson, R. J. Crawford, and Peter Clarke. It may also here be mentioned that with hardly an exception the men temporarily employed as field hands during the past few years have volunteered for active service, and at least two have laid down their lives for King and country.

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* See Special Report No. 7, p. 17.

† Phosphatic pebbles or concretions have lately been found in the Clarence Valley by Dr. J. A. Thomson (verbal communication).

Conclusion.

During the next few months several important reports have to be prepared, and others edited as they pass through the press. Next season's field-work has not yet been decided, but it is hoped to continue detailed geological survey in Taranaki, and to undertake the preparation of an exhaustive report on the lime and phosphate deposits of the Dominion. This work will necessarily entail a number of visits to various parts of New Zealand.

In conclusion, the advisability of undertaking a soil survey of the Dominion may be urged. It may be suggested that this object could best be accomplished by the Agricultural Department and the Geological Survey working in conjunction. In some countries soil surveys are being made by a special staff attached to an Agricultural Department or Bureau, whilst in others they are under the control of the Geological Survey. In a small country such as this a combination of the two systems will probably give the happiest results.

P. G. Morgan,
Director, Geological Survey.

SPECIAL REPORTS.

1. EGMONT SUBDIVISION.

(By P. G. Morgan.)

During the past two seasons some interesting physiographic and geologic data have been obtained in the Egmont Subdivision, which, it will be remembered, includes the survey districts of Wairau, Cape, Egmont, Huiroa, and Ngatimaru, and contains the greater part of the great volcanic cone of Egmont. The following incomplete notes on the physiography and geology of the area are given in advance of the detailed report to be written during the coming winter.

Physiography.

The dominating physical feature of Taranaki is Mount Egmont, a wonderful extinct volcano, 8,260 ft. high. All lines of evidence point to the fact that in a geological sense no great space of time has passed since the last exhibition of volcanic activity in this part of New Zealand, but at the present time not the slightest sign of vulcanism can be perceived, unless it is the existence of a solitary tepid spring on the lower slopes of Mount Egmont. The flanks of this mountain show almost in perfection the catenary curves that are characteristic of the typical volcano built mainly of fragmentary material ejected from a single vent. Its symmetry has as yet been little affected by erosion, and is almost unbroken by parasitical cones, with the exception of Fantham's Peak, a somewhat pronounced excrescence high on it southern side, and two small dome-shaped bumps far down the southern slopes. The north-western slope of Egmont does not reach a low level, but meets the Pouakai Range, an irregular and somewhat deeply dissected mountainous mass of andesitic agglomerate, with minor flows and dykes of andesite. The highest point, Pouakai Peak, is 4,590 ft. above sea-level. Without doubt the Pouakai Range represents a great extinct volcano, older than the present Mount Egmont, but not necessarily materially older than its hidden central portion or core. A flat semi-swampy area between the main part of the Pouakai Range and Mount Egmont, surrounded for three-fourths of its circumference by peaks and spurs of the Pouakai, indicates the position of the main crater.

Between the Pouakai Range and the coast are the Kaitake Hills, with Patua Peak, 2,240 ft. high, as their highest point. They also are of volcanic origin, and bear the same relation to the Pouakai Range as that does to Mount Egmont.

The lower slopes of Mount Egmont and the Pouakai Range pass imperceptibly into a gently sloping plain, well developed near Inglewood and to the south, where it is only very slightly incised by the streams that traverse it. In a general way this plain, though dissected by streams, may be traced to the north-west through Koru to Oakura, and thence westward into the country near Cape Egmont, where it again opens out into a plain, diversified, however, by the innumerable low rounded elevations hereinafter designated "conical hills." Southward the Inglewood plain extends through Stratford to Hawera, and becomes merged in the great Wanganui coastal plain; but from the Stratford-Hawera district it also extends westward and northward to Manaia and Opunake, thus ultimately completely encircling Mount Egmont, together with the closely allied Pouakai Range and Kaitake Hills.

The Inglewood plain is bounded on its northern side by the Tapuae-Manganui Ridge, described by Clarke.* This ridge, extending from near Oakura to Inglewood, may be regarded as a relatively elevated portion of the Inglewood plain. It is intersected by a number of streams, notably the Waiongona, which has formed a broad valley across it, now followed by the railway-line from Inglewood to Lepperton. The summit of the so-called ridge is formed of a number of subsidiary even-topped ridges, all sloping regularly seawards—that is, away from Mount Egmont.

If one disregards the valley of the Manganui the Tapuae-Manganui Ridge may be said to merge into the low ridges of similar or somewhat greater height that extend towards the Waitara

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* Clarke, E. de C.: "The Geology of the New Plymouth Subdivision, Taranaki Division." N.Z. G.S. Bull. No. 14, 1912, pp. 5 and 8.

River, and are prominent in the eastern part of Huiroa Survey District and throughout Ngatimaru Survey District. To the main water-divide—that between the Waitara and Patea watersheds—the name "Te Wera Ridge" was given in Mr. Gibson's report of last year. The Te Wera Ridge, however, is no more prominent or of greater elevation than its neighbours.

Most interesting are the small conical hills mentioned by Clarke as occurring near Inglewood, and also at Lepperton, in the New Plymouth Subdivision. These generally consist of coarse angular agglomerate, with some finer material, but in some cases may correctly be described as formed of shattered andesite. The Inglewood hills have a thick covering of tufaceous loam, and only where they are dissected by streams (a rare case) or opened by quarries can their true nature be ascertained. Near Warea and Cape Egmont similar conical hills occur by hundreds, if not thousands. Many of these have been opened by quarries, and many others, owing to dissection by streams or by the sea, or owing to the part removal of their soil covering, show outcrops, mainly of agglomerate, but in a few cases of shattered andesite, exactly as at Inglewood, and, it may be added, at Lepperton. There can be no doubt that each of these conical hills represents a minor centre of eruption. There are many cases of two or more being confluent, and in some areas, notably east of Warea, there are numerous low irregular ridges that no longer show distinct points of eruption, partly owing to modification by stream erosion.

In the western part of the subdivision the streams radiate from Mount Egmont and the Pouakai Range. Many flow direct to the sea, whilst others join the Waitara River. On the southern boundary are some of the headwaters of the Patea River. Though in the main of consequent characters, those streams that intersect the Tapuae-Manganui Ridge are to be termed antecedent in that part of their course. The eastern part of the subdivision is drained partly by the Waitara River and partly by tributaries of the Patea River. Here the drainage is irregular, and the various streams are deeply incised in a series of sedimentary rocks. The manner in which the drainage of this area has been diverted to the north or to the south by the piling-up of volcanic material in the Mount Egmont region is worthy of note. Attention has previously been drawn to this peculiarity by Clarke.*

Immediately westward of the New Plymouth Subdivision the coast is backed by high cliffs consisting mainly of agglomerate and broken only by the various streams that enter the sea. Westward of Oakura River the cliffs lessen in height, and near the mouth of the Stony or Hangatahua River disappear for a considerable distance. Southward of Stony River low cliffs of tuff and agglomerate are again seen. These continue, with interruptions, past Cape Egmont to the southern boundary of the subdivision. North and south of the mouth of the Hangatahua River, at the mouth of the Kapoaiaia Stream near Cape Egmont, and immediately south of Cape Survey District on the coast of Opunake Survey District, are insignificant sandhills. At low tide a wide beach, consisting in most localities mainly of angular boulders, is exposed. North and south of the Hangatahua River are sandy stretches of some length. Each of the larger streams, such as the Teikaparua and the Kapoaiaia, also has a little sand and shingle at its mouth, especially near high-water mark. Near the southern boundary of Cape Survey District a continuous belt of sand and shingle begins above half-tide mark and continues southward. Seaward the beach is formed mainly of angular andesitic boulders, as to the northward

General Geology.

Table of Formations.—The rock-formations of the Egmont Subdivision are approximately indicated by the following table:—

Name of Series.	Nature of Rocks.	Approximate Age.
——	Stream gravels, &c., swamp deposits, sand-dunes, marine sand, and shingle	Recent.
——	Marine sand and shingle (raised beaches), stream deposits, peaty lignite	Late Pleistocene.
Upper Pouakai	Andesitic lavas, tuffs, and agglomerates (of conical hills), marine sandstone and conglomerate	Pleistocene.
	Local unconformity.	
Lower Pouakai	Andesitic lavas, tuffs, and agglomerates ..	Upper Pliocene.
	Unconformity (of local type).	
Upper Onairo	Claystones, sandstones, pebble-beds, shelly limestones, and conglomerates	Middle and Lower Pliocene.
Lower Onairo (not outcropping in subdivision)	Claystones, sandstones, limestone, greensandstones, marly clays, coal-seams, &c.	Miocene.

General Description.—The oldest rocks visible in the subdivision are a set of claystones, sandstones, pebble-beds, shelly limestones, and calcareous conglomerates, which, as indicated by their fossils, are approximately of Pliocene age. These rocks belong to the upper part of E. de C. Clarke's Onairo Series, so named from a supposed typical development at the mouth of Onairo Stream, west of Urenui. The lower or Miocene part of the Onairo Series is nowhere known to be

* Clarke, E. de C.: *Op. cit.*, p. 8.

exposed at the surface in the Egmont Subdivision, and whether it has any development in the New Plymouth Subdivision west of Urenui seems doubtful. The Upper Onairo is well developed in the Ngatimaru Survey District and in the eastern part of Huiroa Survey District. To the westward it is unconformably overlain by an increasing thickness of volcanic debris belonging to the upper horizon of Clarke's Pouakai Series. At a distance of twelve or thirteen miles from the summit of Mount Egmont outcrops of Onairo rocks disappear, and to the westward only Pouakai and small patches of younger rocks are visible.

The Onairo rocks are in general almost horizontally bedded. In some localities they show evidence of gentle but irregular folding, accompanied in one or two cases by slight faulting.

The Lower Pouakai rocks consist of andesitic agglomerate and tuff, with contemporaneous andesitic lava-flows and dykes. In many places they show bedding to such an extent as to prove some measure of transportation and sorting of water, but water-worn material is nowhere present to any marked extent. To the Lower Pouakai are assigned the rocks of the Kaitake and Pouakai ranges (with the exception of surface material) and the agglomerates exposed in the valleys of the Oakura and Timaru streams and along the sea-coast from the boundary of the New Plymouth Subdivision to a point west of Oakura. Probably also the core of Mount Egmont belongs to the Lower Pouakai.

On the coast-line near the mouth of the Tapuae Stream there is evidence of a distinct break between the lower and the upper portions of the Pouakai Series Here a thin inconstant conglomerate, followed upwards by a soft sandstone (probably partly marine and partly æolian) rests with clear unconformity upon agglomerate. The same unconformity appears on the coast at New Plymouth, but has not been traced to the west of Oakura.

In the main the Upper Pouakai rocks consist of fine tuff (generally horizontally bedded) and volcanic ash, but to them are also assigned the agglomerate and andesitic masses forming the conical hills previously mentioned, the lava-flows and fragmentary material that build up the visible portions of Mount Egmont, together with the sandstone and conglomerate mentioned above, and some contemporaneous fluviatile and marine debris. The tufaceous loam that forms the soil and subsoil of nearly all western Taranaki may be considered as part of the Upper Pouakai Series.

Whilst the Upper Pouakai Series is necessarily unconformable to the Onairo rocks, as may be seen at various localities in the Huiroa Survey District, the relation of the Lower Pouakai Series to the Onairo Series is more doubtful. It is practically certain that the volcanic eruptions that built up the Kaitake Hills and the Pouakai Range began while the deposition of Onairo rocks was still proceeding in adjoining areas, and therefore complete unconformity cannot exist. No doubt in places there is some degree of local unconformity, and this seems also to be Clarke's view, though his remarks on the subject in the New Plymouth Bulletin* may perhaps be construed in a slightly different sense.

Rocks younger than the Upper Pouakai Series have an extremely limited distribution. Their nature is sufficiently indicated in the table of formations given above.

Economic Geology.

Soils.—Practically everywhere on the lower slopes of Mount Egmont and on the adjoining country, on the Pouakai Range except on the highest points, and on the Kaitake Hills, one type of soil—a brown loam derived from decomposed volcanic tuff and ash—prevails. This is generally underlain by a deep subsoil of almost the same character except for the absence of vegetable mould, but on the west side of Mount Egmont, and also near the so-called "radius line"† (boundary of Egmont National Reserve) on the east side, the subsoil is generally shallow, and in places not more than 1 ft. or 18 in. of loam is seen above the bed-rock—cemented grey tuff or agglomerate. The only other classes of soil found in the western part of the subdivision are the peaty soil of swamps bordering small watercourses or occupying small undrained areas (most of which are towards the coast), the gravelly soil of a few small stream-flats or terraces, and the sandy soil of dune-areas near the coast. Eastward from the central portion of the subdivision the volcanic soil gradually becomes mixed with more and more material derived from the Onairo rocks. The change is first apparent near the Manganui Stream, and in Ngatimaru Survey District the soils, except in swamp areas, are formed almost wholly of weathered sedimentary material. The volcanic constituents that seem to be present in some of the river-flat soils are probably derived from the central part of the North Island, and not from the Mount Egmont area.

Metallic Ores.—The Kaitake or Patua Range has been prospected at intervals for gold, silver, and copper. Owing to the presence of quartz lodes and silicified pyritized belts of country which on assay are generally found to carry traces of gold, a litlte silver, and occasionally some copper, hopes of developing successful mines have been entertained, but no real justification for such expectations has been found.

Manganese oxide occurs in small quantity at various places, for example, near Tipoka Road, in the neighbourhood of Cape Egmont. Near Puke-iti Hill, between the Kaitake and Pouakai ranges, is a deposit of low-grade rhodochrosite (carbonate of manganese).

Very small deposits of magnetic oxide of iron (ironsand) occur on the coast of the subdivision. These have no commercial value.

Limestone and Calcareous Sinter.—The bands of shelly limestone in the Onairo Series are too small and, as a rule, too impure to be of much value for agricultural purposes. Deposits of calcareous sinter occur (1) south of German Hill, a dome-like elevation five miles west-south-west of Inglewood; (2) three miles south-south-west of Inglewood, on a branch of the Waiongona-

* Clarke, E. de C.: *Op. cit.*, pp. 14 (table of formations) and 25.

† This term, locally applied to the boundary of the many-sided polygon that constitutes the Egmont National Reserve, is a complete misnomer.

iti Stream; and (3) south of upper Kahui Road, near the southern boundary of the subdivision. The largest of these deposits is that near German Hill, but even this is too small to be of any appreciable commercial value as a source of lime.

Roadmaking Materials.—The greater part of the Egmont Subdivision is well supplied with road-making material. Stone for that purpose is obtained from the stream-beds and from the conical hills which are abundant near Inglewood, and much more so in the Cape Egmont district. The Railway Department obtains ballasting-rock from the quarry on the eastern slope of Mount Egmont mentioned in last year's annual report. As yet nothing further has been done with respect to the Public Works quarry, also mentioned in the same report.

In the eastern part of Huiroa Survey District and in Ngatimaru Survey District volcanic rocks are absent, and the chief road-making material is supplied by a few bands of shelly limestone or conglomerate in the Onairo rocks. East of Tarata pebbly bands are not uncommon in the sedimentary rocks, and have furnished a considerable amount of material for the roads.

Petroleum.—Various indications of petroleum, chiefly in the form of gas-emanations, occur in the subdivision. Three bores* in search of oil have been drilled, these being (1) the Moa bore, near Inglewood; (2) the Norfolk Road bore, near the railway, several miles south-south-east of Inglewood; and (3) the Huiroa bore, near Huiroa. The last-named bore has reached a depth of over 4,200 ft., and boring operations are still continuing. Discussion of the petroleum prospects must be deferred to the detailed report on the subdivision now in course of preparation.

Water-power.—A considerable amount of water-power can be obtained from the various streams traversing the lower slopes of Mount Egmont and the Pouakai Range. The Ngatoro Stream supplies electrical energy for the lighting of Inglewood, and the Borough of Stratford, south of the subdivision, is similarly lighted by means of power derived from the Patea River.

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2. GISBORNE AND WHATATUTU SUBDIVISIONS.

(By J. Henderson and M. Ongley.)

Work in the Gisborne Subdivision has been carried on for two field seasons under the charge of Dr. Henderson, who, however, has been occupied with other work during considerable portions of the two periods. Mr. M. Ongley, Assistant Geologist, has been responsible for most of the field-work. The survey districts of Uawa, Waikohu, Waimata, Whangara, Patutahi, and Turanganui, in all an area of about 790 square miles, have been examined in detail, and the writers have also made a brief inspection of Mangatu and Waingaromia survey districts, which were reported on by J. H. Adams in N.Z.G.S. Bulletin No. 9 (New Series), 1910. For the most part the weather has been favourable and the work has not been difficult.

Topography.

The Raukumara Division forms the eastern portion of the old province of Auckland, and comprises a broad belt of moderately elevated country to the north of Hawke Bay, lying, for the most part, eastward of the dividing-range of the North Island. The area examined consists chiefly of uplands, now deeply dissected, but which still exhibit remnants of an ancient surface maturely sculptured during a time when the land stood considerably below its present level. The elevation of this ancient surface was intermittent, as is proved by the occurrence along the major streams of three well-marked terrace series. Corresponding with these are raised beaches near the coast at heights of about 560 ft., 220 ft., and 15 ft. respectively. There is also proof that the land once stood at a higher level than at present, and the infilled lower valleys of the old rivers form the only lowlands of the subdivision.

General Geology.

The oldest rocks of the Raukumara Division, consisting of beds of greywacke and argillite, referred to the Trias-Jura system, are exposed at various points along the mountain axis, and thence eastward in a general way younger formations appear successively as the sea is approached. In the Gisborne and the adjoining Whatatutu Subdivision these ancient rocks do not outcrop, although the various younger series are well represented. In descending order these are:—

Alluvium, terrace and subaerial deposits	(Quaternary)
Waipaoa Series	(Pleistocene).
Tawhiti Series	(Upper Miocene).
Turanganui Series	(Lower Miocene).
Waikohu Series	(Eocene ?).
Mangatu Series	(Cretaceous).

These formations, with the exception of the greater portion of the Quaternary and Pleistocene deposits, are of marine origin, and indicate that most of the area examined was under the sea during late Mesozoic and Tertiary times. Yet the unconformities separating the series one from another show that the geological record is by no means complete, and that several periods of deformation are represented.

Mangatu Series.—A thick series of beds believed to be of Cretaceous age forms the north-western portion of the Mangatu Survey District, where also occurs the highest land of the area examined. These rocks may be divided into a lower group consisting chiefly of shales, and an

* According to Mr. E. de C. Clarke's maps the New Plymouth Petroleum Company's Omata bore is on the eastern boundary of Wairau Survey District. (See N.Z. G.S. Bull. No. 14, 1912, pp. 37, 53, and maps.)

upper containing greensand, limestone, claystone, and their various gradations. These rocks have been subjected to decidedly more disturbance than the overlying Tertiary series, and with the exception of the claystone are readily distinguishable from them in hand-specimens.

Waikohu Series.—The rocks of this series occupy a considerable area in the Mangatu and Waikohu survey districts. They extend from the Mangatu River to the Hihiroroa Stream, and have their chief exposure along the river after which the series has been named. They consist chiefly of clay-shales and sandstones in thick layers, and also in very rapid alternations of the same rocks. Fault junctions between this and the preceding series occur at several points, but a junction of deposition was nowhere observed. The lowest rock noted was a conglomerate or breccia-conglomerate bed, perhaps 50 ft. thick, consisting of angular, subangular, and rounded fragments of limestone and calcareous claystone, evidently derived from the Cretaceous beds, and proving the unconformable relationship of the Mangatu and Waikohu rocks.

Turanganui Series.—In ascending order the Turanganui Series consists of carbonaceous sandstone and grit, locally passing into conglomerate, followed by a thick deposit of structureless claystone which towards the top becomes more sandy, and grades into alternating beds of sandstone and claystone. The conglomerate is composed chiefly of rounded pebbles of igneous rock, but contains also pieces of claystone and limestone, some small and rounded, others large and angular. As a whole the rocks of this series resemble those of the Waikohu Series, but are less sandy and are softer. The relationship to the latter series is unconformable; angular unconformities may be seen in the Wheao and Mangatu streams.

Tawhiti Series.—The name "Tawhiti Series" was applied by Sir James Hector to a great thickness of beds of clay- and sand-stone covering large areas in the Raukumara Division. The formation is characteristically developed at Tawhiti Hill, near the coast, four miles north of Tokomaru Township. In a general way the succession of beds resembles that of the preceding Tertiary series, but the rocks are decidedly more arenaceous and fossiliferous. Fossil Mollusca and Brachiopoda are very common, and thick extensive layers of sandy limestone occur, especially in the southern portion of the area examined. These Hector and McKay separated under the name of the "Ormond Limestone." The Tawhiti Series in the Gisborne and Whatatutu subdivisions is unconformable with the Turanganui beds. There are numerous sections definitely proving this relationship, although in one or two localities an appearance of conformity has been found. The Tawhiti beds are believed to be of Upper Miocene age, but they possibly extend into the Pliocene.

Waipaoa Series.—The movements that brought the Tertiary epoch to a close resulted in the uplift of the sea-floor and its sculpturing by subaerial denudation. During the period of depression that followed the valleys formed when the land was elevated were filled with gravels and pumice sands. These form the Waipaoa Series, and are considered of Pleistocene age.

Recent Deposits.—During Recent times the land has been intermittently elevated, and raised beaches at various heights, as previously noted, occur along the coast. These, together with sand-dunes, the terrace and flood-plain gravels of the streams, and also aerial pumice, form the Recent deposits of the subdivision.

Volcanic Rocks.—The Raukumara Division lies at no great distance from the volcanic belt of the North Island. Although no dyke or flow rocks are known to occur within it, there are numerous layers of fine-grained fragmental material of volcanic origin in the Tertiary rocks. The oldest of these were noted in the upper portion of the Turanganui Series. During the deposition of the Tawhiti beds pumiceous material was increasingly abundant, and reached a maximum towards the close of that period. The Waipaoa beds are largely composed of pumice of subaqueous deposition, while similar material of subaerial origin covers the remnants of the maturely sculptured uplands not yet destroyed by the rejuvenated streams.

Economic Geology.

The geological survey of the Whatatutu and Gisborne subdivisions was undertaken on account of the presence in the area of numerous mud and salt-water springs. From many of these inflammable gas emanates, while a few also yield traces of petroleum. In the great majority of cases it can be definitely shown that the springs are connected with faults, while in the others the structure is doubtful. On Waitangi Hill the gas and oil come from rocks of Cretaceous age, and according to Hector and McKay a like condition obtains in the Waiapu district lying to the northward. At Kaiti Headland, at Totangi, and in the Waimata Valley Cretaceous rocks either occur *in situ* near the springs, or fragments of them are contained in the wide zones of pug and crushed rock from which the gas emanates. At Waihirere (near Ormond) there is no trace of pre-Tertiary rocks. It cannot be doubted but rocks of Cretaceous age underlie the whole of the Gisborne Subdivision, and there seems no reason why an alternative source for the oil should be sought.

In Bulletin No. 9, dealing with the Whatatutu Subdivision, the rock structure was considered to have arisen from the crumpling of the beds into a complex series of folds. The present writers entirely dissent from this interpretation. In their view the tilting of the strata has been caused by faulting. What folding does occur is in close connection with the fracture-zones, and the deformations produced thereby are of quite insignificant amount. The main fault-belts cross the area in an east-and-west direction, and the major blocks thus formed are again subdivided by minor fractures having a north-north-east orientation. The strikes and dips observed in the various blocks are too irregular to admit of any brief account of structural details being given in the present report. In all boring hitherto undertaken but little heed was given to the geological structure, which appears to have been misunderstood, and in every instance the wells have been put down in faulted ground near seepages and springs. As a result the unfaulted country has not been tested. But the prospecting of the possible oil-bearing areas will be difficult and expensive, and should not be undertaken except by a company prepared to stand the loss. Yet the indications of petroleum are so favourable that a trial is warranted. The preliminary geological examination of an oil-area may be reduced to the answering of three questions: (1) Is there any oil-formation in the district? (2) What is the horizon of the oil-formation? (3) What is the structure of the strata? The fact that oil has been struck in wells in moving fault-pug where no one would expect to find it even in a proved oilfield seems to indicate that oil occurs in quantity. But it is questionable whether the oil has had an opportunity of accumulating in a sandstone or other pervious rock capable of acting as an oil-reservoir. The rocks to be tested are with one exception fine-grained and argillaceous, and would suit well for the impervious cap-rock, but could not serve as the reservoir. The single exception is the chalky limestone of Cretaceous age, which is itself a close-grained dense rock, but is broken and fissured. It is possible that this may afford storage for oil. The conglomerates are compacted and cemented with clay, and possess little or no pore space. No bore has yet reached the horizon of the limestone, where alone the occurrence of oil in quantity seems probable.

With bores beginning in the Turanganui Series, as in the case with most of those already sunk, and as must also be the case with the majority of future bores in the Gisborne and Whatatutu subdivisions, two unconformable junctions have to be passed. It is therefore impossible to say anything about the structure or the depth of the limestone. When additional work has been done in areas farther north and west more will be known about this stratum, which at present seems to be the only possible oil-reservoir. Where the blocks are tilted the fault-zone will serve as one impervious limb of the anticlinal, and the best hope of striking oil seems to be in boring in the solid country some distance from the faults in such a manner as to strike the limestone at a reasonable depth.

Macadamizing-material.

Really good macadamizing-material is not procurable in the district. The limestone of the Tawhiti Series is quarried in several places for roadmaking purposes. Beach and river gravels in some localities also afford material of fair quality. A quarry is being opened in Motuhora, a hill of greywacke and argillite in Motu Survey District, fifty miles north-west of Gisborne. The greywacke of this locality seems to be the best stone for road-making procurable in or near the Gisborne district.

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3. WAIHI.

(By P. G. Morgan.)

In October, 1914, and again in September, 1915, I made short visits to Waihi, and inspected portions of the underground workings of the Waihi and Grand Junction mines. The following notes embody various features of interest observed in these two mines:—

Waihi Mine.

In 1914, during the driving of the Bath crosscut north-north-west from the Dreadnought to the Martha lode, three carbonaceous seams interbedded with tuff and fine breccia were intersected at 100 ft. to 127 ft. from the Dreadnought lode. The following description, with slight verbal alterations, is quoted from the report of Mr. J. L. Gilmour, mine-manager, published in the Waihi Gold-mining Company's annual report for 1914, pages 24–25: "From 71 ft. to 100 ft. (north-north-west of the Dreadnought lode) brecciated grey dacite is seen. At 100 ft. a black carbonaceous seam about 1 ft. wide was met. It is dipping south-east at 28° from the horizontal. From 101 ft. to 109 ft. is made up of thin layers, which are probably volcanic ash. From 109 ft. to 109½ ft. is a black carbonaceous seam parallel to the black seam at 100 ft. From 109½ ft. to 127 ft. is mostly made up of thin layers, probably volcanic ash. At 127 ft. there is a thin carbonaceous seam about 1 in. wide, dipping south-east at 35° from the horizontal. From 127 ft. to 130 ft. is made up of thin layers, probably volcanic ash, parallel to the black seam at 127 ft." Analyses of the carbonaceous bands show the presence of 1·5 and 1·57 per cent. of free carbon.

The locality where these surface-formed layers occur is towards the centre of the area mapped by Dr. J. M. Bell and Mr. C. Fraser as "intrusive dacite."* This they regard as by far the most favourable class of country for the presence of profitable ore-shoots. The discovery of bedded material in the heart of the supposed intrusive rock makes it certain that Bell and Fraser's diagnosis of the geological structure of the Waihi Mine was to some extent erroneous. Recently Mr. Arthur Jarman, of the Waihi Grand Junction Company, has written a paper entitled "The Geology of the Waihi Grand Junction Mine,"† in which he marshals a considerable amount of evidence in favour of the thesis that the supposed intrusive dacite has the characters of a succession of lava-flows. In reviewing this paper the editor of the *Mining Magazine*‡ again draws attention to the close resemblance between the geology of Waihi and that of Tonopah, Nevada (a resemblance first noted by myself§), and suggests that at Waihi there are intrusive masses or

* N.Z.G.S. Bull. No. 15, 1915, p. 125.

† Published about October, 1915, by the Institution of Mining and Metallurgy as a paper to be discussed at the meeting on the 21st October. See also the discussion on this paper, published some time later.

‡ The *Mining Magazine* vol. xiii, November, 1915, pp. 251–252. (See also p. 281.)

§ Morgan, P. G.: "The Hauraki Goldfields, New Zealand," *Engineering and Mining Journal*, vol. lxxix, May 4, 1905, pp. 861–862. (See also Spurr, J. E.: "The Geology of the Tonopah Mining District, Nevada," U.S. Geol. Sur. Prof. Paper No. 42, 1905, pp. 284, 285.)

sills of igneous rock separating the members of a series of lava-flows, as is now believed to be the case at Tonopah. This explanation had previously occurred to me, but since very little evidence in its favour was available, and its validity was thus more than doubtful, publication seemed unnecessary. Though at present in the position of an unsupported hypothesis, it is, however, well worthy of consideration by those interested in mining at Waihi. In concluding this paragraph I may add that the earlier accounts of Waihi geology—those of McKay and Park in 1897* and of myself in 1902†—appear to be substantially correct in their main details, and more especially in their direct or implied statement that the auriferous rocks of the Waihi Goldfield consist of a succession of lava-flows. McKay, however, appears to ascribe too great importance to the tuff and breccia beds present.

The importance of establishing the sheet-like character of the Waihi Goldfield rocks (whether they are wholly flows or partly flows and partly sills) cannot be overestimated, for it follows that the country favourable for gold probably has a lateral extension far beyond the boundaries assigned in Bulletin No. 15. In consequence vigorous prospecting in the areas adjoining the Waihi and Grand Junction mines is justified.

In many parts of Nos. 10 and 11 levels the quartzose lode material of the Waihi Mine is associated with oxides of iron and manganese. Veinlets and small pockets or patches of sulphide ore, in some places carrying ruby-silver or pyrargyrite, occur even in the poorer parts of the lodes. Inclusions of country, large and small, are numerous in the more important veins, and as a rule are surrounded by good ore. This is quite in accord with the old mining rule that "a horse pays for itself." Replacement of country by lode material is well shown by hand-specimens of the inclusions. In the Royal and other lodes patches of soft chloritic material generally carry gold and silver in such amount as to render the whole lode profitable where they are numerous. On the whole, calcite and quartz pseudomorphous after calcite are much less prominent than in some of the upper levels. Near the larger lodes, such as the Martha, oxidation extends into the joints and crevices of the country, as is shown by the presence of iron and manganese oxides.

The abundance of oxides of iron and manganese, the open vuggy character of the larger lodes, the presence of thin sulphide veins containing ruby-silver, and the scarcity of calcite all seem to point to secondary enrichment at a lower level. That ore-shoots equal in extent and value to those of the upper levels in the Waihi Mine will again be encountered does not seem likely, but the outlook for the future is by no means unhopeful.

Grand Junction Mine.

The ore-bodies in the No. 7 level of the Grand Junction Mine are similar in most respects to those of the Waihi Mine. The lodes branch and reunite both on a large and a small scale, thus forming horses of varying size. Some of the faces and backs (roofs) of levels driven on the lode courses exhibit a series of branching veinlets enclosing lenses of country, the appearance being therefore that of small stockworks. As in the Waihi Mine, soft chloritic ore is of good grade. In places rhodochrosite (carbonate of manganese) is associated with the better grades of vein stone.

In various places, especially in the eastern part of the workings, the branches of the Empire and other lodes widen and contract at intervals. Another feature is that the lodes not uncommonly make a sudden bend where ore pinches, and resume their original direction ten to twenty feet to one side, the appearance being that of a fault; but the true explanation seems rather to be that the country having been jointed, fissured, and shattered prior to lode-formation on two sets of nearly vertical planes, ore-deposition in various cases took place for some distance on one joint or fissure, and then migrated to another parallel plane a few feet away. Probably the same phenomenon happens on the dip as well as the strike of the lodes—that is to say, the lodes, or some of them, suddenly shift on a nearly horizontal plane to one side or the other.

Water.

In September, 1915, the water pumped by the Waihi Gold-mining Company was estimated at 500 gallons per minute, whilst the Waihi Grand Junction Company was pumping about 630 gallons per minute. The water entering at the bottom of the shaft was stated to have a temperature of 98° to 100° F.

In 1902 the Waihi Gold-mining Company pumped water at the rate of 835·6 gallons per minute, and in 1903 at the rate of 683·2 gallons per minute.‡ In the latter year the Waihi Grand Junction Company also pumped a considerable amount of water, but the permanent flow at the Waihi No. 6 level (555 ft. below the collar of No. 1 shaft) was then estimated at not much more than 600 gallons per minute for the whole of the Waihi mines.‡ It is evident that the deepening of the mine-workings by approximately 750 ft., together with the increased area of ground drained, has caused a large increase in the amount of water pumped. Again, since 1903 the temperature of the water pumped has increased by at least 20° F.

* McKay, Alexander: "Report on the Geology of the Cape Colville Peninsula, Auckland." C.-9, 1897. (See pp. 59–60.) Park, James: "The Geology and Veins of the Hauraki Goldfield." Trans. N.Z. Inst. Min. Eng., vol. i, 1897. (See pp. 86–95.)

† Morgan, P.G.: "Notes on the Geology, Quartz Reefs, and Minerals of the Waihi Goldfield." Trans. Aust. Inst. Min. Eng., vol. viii, Part II, 1902, pp. 164–187.

‡ Morgan, P. G.: "Water in the Hauraki Goldfield, New Zealand." Eng. and Min. Journ. (New York), vol. lxxviii, 1904 (15 Sept.), p. 429.

4. KAIPARA DISTRICT, NORTH AUCKLAND.

(By P. G. Morgan.)

In September, 1915, I spent two days at Kaipara Flats, and during that time visited the mouth of the Hoteo River. I then proceeded to Maungaturoto, and thence to Pahi, where two days were occupied in the examination of Pahi Peninsula and in a launch trip to Komiti Bluff and Gibraltar Rock.

Physiography.

The greater part of the district examined is occupied by hills and ridges a few hundred feet in height, with some intervening river-flats and the "wide maturely sculptured depression . . . known as the Kaipara Flats."* The most striking physiographic feature is presented by the numerous drowned valleys which allow the sea to penetrate far inland and form the intricate shore-line of Kaipara Harbour. The depression thus indicated has been offset to some extent by slight subsequent elevation, shown by an entrenching of the streams in their main valley-floors and by a few probable wave-cut terraces about 20 ft. above high-water mark seen on the shores of Kaipara Harbour.

General Geology.

Owing to the briefness of my visit to the Kaipara district nothing of material importance can be added to the accounts given by Cox, Park, and other previous observers. Cox's sketch-map of 1881† appears to represent the geology of the district with a considerable degree of accuracy. It may be stated, however, that numerous strong faults traverse the area, and render its geological structure decidedly complex. Many of these are of post-Miocene age, but it is not improbable that some originated between the Cretaceous and the Miocene periods.

Unconformity between Miocene and Cretaceous Rocks.

According to the reports by Cox and Park, one or more angular unconformities may be detected in the rocks of the Kaipara district. Owing to faulting or to the obscurity of the stratigraphical relations, some of their sections showing unconformity—for instance, that of Cox in the upper part of the Pahi Estuary near Captain Colbeck's old residence‡—are unsatisfactory.

A clear angular unconformity between Miocene and probable Cretaceous rocks may be seen at the south-east corner of Komiti Peninsula, at the point where Arapaoa Arm joins the Otamatea Estuary, three miles east-north-east of Komiti Bluff. This no doubt is the unconformable section mentioned by Hector,§ Cox,|| and Park¶ as occurring at or near Komiti Point. Owing to adverse weather-conditions I was unable closely to examine the section, which as viewed from the sea appears to consist of a yellowish sandstone resting with moderate angular unconformity upon concretionary greenish clays.

At Kaipara Flats unconformity is indicated between Miocene and Early Tertiary or Cretaceous by the occurrence of conglomerate with pebbles of hydraulic limestone and of limestone of the Gibraltar Rock type.**

Economic Geology.

Coal.—In the third gully south of Mr. Thomson's house, near Kaipara Flats Railway-station, the horizontally bedded marine sandstone contains tiny lenticular seams of plant-remains converted into coaly material. These cannot be regarded as indicative of workable coal-seams, but merely of the fact that while the sandstone was forming on the sea-bottom pieces of wood and other vegetable matter transported by streams to the sea were embedded in it. No. 1 of the following analyses†† shows the composition of the coaly seams. No. 2, given for comparison, is the analysis of carbonized wood from the coal-measures in Miller Creek, State Coal Reserve, Greymouth:—

	(1.) Per Cent.	(2.) Per Cent.
Fixed carbon	34·42	43·61
Volatile hydrocarbons	38·16	30·22
Water	15·63	19·17
Ash	11·79	7·00
	100·00	100·00
Total sulphur	1·43	0·34
Specific gravity	1·38	..

* Henderson, J.: "Coal Possibilities of the Warkworth Flats." N.Z.G.S. Eighth Annual Report, published in C.-2, 1914, p. 157.
† Cox, S. H.: "Geology of the Rodney and Marsden Counties." Rep. Geol. Explor. during 1879–80, No. 13, 1881, map opposite p. 28.
‡ *Op. cit.*, p. 19.
§ Hector, J.: "Progress Report" in Rep. Geol. Explor. during 1874–76, No. 9, 1877, p. v.
|| Cox, S. H.: *Op. cit.*, pp. 17, 33, 37; "North Auckland District." Rep. Geol. Explor. during 1881, No. 14, 1882, p. 23.
¶ Park, James: "Kaipara and Wade Districts, Auckland." Rep. Geol. Explor. during 1886–87, No. 18, 1887, pp. 221, 228.
** In this connection see Henderson, J.: "Coal Possibilities of the Warkworth District," N.Z.G.S. Eighth Annual Report, in C.-2, 1914, pp. 157–158.
†† These and subsequent analyses, unless otherwise stated, are the work of Dr. J. S. Maclaurin, Dominion Analyst, and his staff.

Rock Phosphate.—Various specimens of calcareous rocks collected near Kaipara Flats on being qualitatively tested gave at most a faint reaction for phosphate. A fragment of limestone taken from a breccia-conglomerate, with pebbles consisting mainly of volcanic rock, which outcrops in a branch of the third gully south of Mr. Thomson's house, gave a good reaction, but on being analysed yielded only 0·65 per cent. of phosphoric anhydride, equivalent to 1·42 per cent. of tricalcic phosphate.

Near the mouth of Hoteo River nothing resembling rock phosphate could be observed. Various samples of calcareous and other rocks collected in this locality on being tested gave only a slight reaction for phosphoric anhydride.

A concretion collected on the west side of Pahi Peninsula, less than a mile north of the hotel, was found to be strongly but irregularly phosphatic. Of the following analyses No. 1 represents the fine-grained part of this concretion, and No. 2 the coarse-grained part:—

	(1.) Per Cent.	(1.) Per Cent.
Insoluble in acid	5·18	11·99
Iron oxides and alumina (Fe_2O_3, Al_2O_3)	6·97	10·07
Manganous oxide (MnO)	23·95	39·80
Lime (CaO)	22·92	2·40
Magnesia (MgO)	0·92	3·66
Phosphoric anhydride (P_2O_5)	15·48*	0·32
Carbonic anhydride (CO_2)	19·86	27·97
Moisture, organic matter, and undetermined†	4·72	3·79
	100·00	100·00

Limestone.—Two samples of limestone, collected (1) from Gibraltar Rock, above Captain Colbeck's old residence, and (2) from the east side of the Pahi Estuary below Colbeck's, have been analysed with the following results:—

	(1.)	(2.)
Insoluble in acid	3·13	7·05
Alumina and iron oxides (Al_2O_3, Fe_2O_3)	1·75	1·25
Lime (CaO)	51·92	50·14
Magnesia (MgO)	0·77	1·16
Phosphoric anhydride (P_2O_5)	0·12	0·27
Carbonic anhydride (CO_2)	41·20	39·08
Water and organic matter	1·29	1·42
	100·18	100·37

Roadmaking Material.—In many parts of North Auckland good material for making roads is by no means abundant, and this is especially the case in the Kaipara district. Nevertheless stone suitable for road-making is obtainable in a number of localities, and by means of rail or water transport may generally be conveniently distributed where required.

In the Kaipara Flats district the Miocene sandstone, if moderately calcareous, is in places sufficiently hard to be used for roadmaking. Interbedded with it in some localities are layers of conglomerate or breccia-conglomerate, such as that mentioned above as occurring south of Mr. Thomson's house. The pebbles of this bed, which is 12 ft. or more thick, consist mainly of an andesitic rock, together with some hard limestone and a little hydraulic limestone. North of Kaipara Flats, on Mr. Breeze's land east of the railway, shelly limestone is reported to occur. On the road from Hoteo Railway-station to Tauhoa is a small mass of serpentinized rock, probably originally a gabbro, which has been quarried somewhat extensively. The following analysis shows that the rock is now a fairly typical serpentine:—

Silica (SiO_2)	34·91
Alumina (Al_2O_3)	13·03
Ferric oxide (Fe_2O_3)	2·76
Ferrous oxide (FeO)	4·03
Lime (CaO)	4·44
Magnesia (MgO)	27·46
Potash (K_2O)	0·05
Soda (Na_2O)	0·44
Titanium dioxide (TiO_2)	0·12
Nickel oxide (NiO)	0·04
Copper oxide (CuO)	Nil
Loss on ignition	13·19
	100·47

A similar rock is reported to occur on Mr. Le Gallais's farm to the south-west. The report may refer to the wooded conical hill called Pukekohuku, about a mile and a half south of Tauhoa

* Equivalent to 33·82 per cent. of tricalcic phosphate ($Ca_3P_2O_8$).

† The undetermined is mainly barite ($BaSO_4$), small transparent masses of which were visible in both samples.

Township. Some miles north-west of Hoteo Railway-station is the wooded hill Kikitangeo, which is mapped by Cox as partly "trachyte" (probably andesite).

In the Pahi-Paparoa district there are various outcrops of limestone suitable for roadmaking purposes. The Gibraltar Rock and other outcrops on the Pahi Estuary could be easily quarried and conveniently transported by water to many points. Marahemu Hill, east of Pahi, consists of an andesite or allied rock, which forms excellent road-metal. A similar hill occurs west of Matakohe Township, Komiti Peninsula. Near Komiti Bluff, and again on the southern side of the entrance to the Otamatea Estuary, are considerable outcrops of volcanic breccia, which give rise to some patches of rough bouldery beach. From these and similar beaches much material for roadmaking can be obtained and easily transported by water to any point on the shores of Kaipara Harbour.

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5. WATER-SUPPLY FOR KAIKOURA TOWNSHIP.

(By P. G. Morgan.)

While at Kaikoura in December, 1915, my attention was directed to the lack of a permanent water-supply for the township. Owing to the dryness of the season all tanks were empty, and water for drinking purposes was being carted several miles. For washing and for watering domestic animals well-water was being generally used. At the Maori settlement on the south side of the peninsula water was being obtained from a small spring in such a position that it could easily be contaminated by surface drainage.

A good supply of pure water is necessary for the health as well as the convenience of the inhabitants of the township. Sporadic cases of typhoid fever occur in the district,* and if present conditions continue it would not be surprising if a severe epidemic of this or some similar disease should break out. Kaikoura has been praised as a seaside resort, and has been termed by its admirers the Scarborough of New Zealand, but it has a poor reputation for salubrity, and so long as it is without a reliable water-supply intending visitors, if in search of health, would do well to avoid this picturesque little township.

The well-water at Kaikoura is obtained from moderately shallow wells sunk in the narrow flat on which the greater part of that straggling township is built. This flat is a raised beach backed by hills of limestone and other rocks, used mainly for grazing sheep. The water that drains into it from these hills is very hard, and contains sufficient lime and other mineral matter to give it a somewhat unpleasant taste. The danger of this supply becoming contaminated and utterly unfit for consumption by human beings or by stock is obvious.

If Kaikoura had a large population an abundant and satisfactory supply of water could be obtained either from the Kowhai or the Hapuku River, but the adoption of either of these schemes involves six to eight miles of pipe-line, at an expense beyond the means of the small community that would be served. There are, however, other possible sources of water-supply, and these may be classified as (I) streams draining the eastern slopes of Mount Fyffe, (II) springs on the Kaikoura Plain, and (III) artesian or sub-artesian water of the Kaikoura Plain.

I. Streams from Mount Fyffe.

(1.) *Luke's Creek.*—Luke's Creek is a small stream draining part of the south-eastern slopes of Mount Fyffe. On reaching the gravel-fans at the foot of the mountain it diminishes in volume through soakage, and ultimately disappears. The creek has been favourably reported upon as a source of water-supply, but at the time of my visit was perfectly dry at the proposed intake, which is on the fan some distance from the base of Mount Fyffe. It is therefore fortunate that no steps were taken to carry out the scheme recommended by the engineer consulted in the matter. Possibly by going westward to the base of Mount Fyffe a fairly permanent supply of water could be obtained from Luke's Creek. The watershed, however, is small, and probably a large reservoir on Kaikoura Peninsula would be needed in order to ensure a constant supply to the town.

Luke's Creek, provided stock are excluded from the watershed, would yield water of unquestionable purity. The pressure at Kaikoura would be ample for all purposes, but the main pipeline would be long, the headworks probably liable to be destroyed by floods, and, as mentioned above, a reservoir near the township would probably be found necessary.

(2.) *Waimangarara Stream.*—This stream, situated to the north of Luke's Creek, has a much larger valley, and if tapped near the base of Mount Fyffe would yield a never-failing supply of good water under high pressure. As with Luke's Creek, a long main pipe would be needed, and the headworks would be liable to be destroyed by floods.

II. Springs on Kaikoura Plain.

On the 19th December, accompanied by Messrs. James Boyd, County Chairman, and J. C. McLauchlan, County Engineer, I visited Hughie's Creek, which has been considered as a source of water-supply, and is a small stream flowing from a spring in the Kaikoura Plain at a spot about three miles north-west of the western end of Kaikoura Township. The gently sloping surface of the plain is here somewhat over 100 ft. above sea-level. At the point between Sections 101 and 159, where Hughie's Creek crosses the road, it has a flow, roughly estimated by me at quite two-thirds of a sluice-head, or 40 cubic feet per minute—that is, sufficient for a population of 7,200, using 50 gallons per head per day. The water is perfectly clear, tasteless,

* Four cases were treated at the hospital in 1914. See "Statistics of the Dominion of New Zealand," vol. i, 1915, p. 141.

and to all appearance eminently suitable for a town supply. A short distance to the north, in Section 168 or 169 is another spring equal in size to Hughie's Creek, so that the supply from the latter source could easily be supplemented if required.

Though I did not have the time or means required for gauging Hughie's Creek, and therefore the estimate of 40 cubic feet per minute as its flow is merely a guess, there need be no doubt but that it will easily fulfil the needs of Kaikoura Township, which according to the census of 1911 contained only 408 inhabitants. Probably the maximum number of people to be supplied at the present time does not exceed six or seven hundred. The past two years have been among the driest ever experienced in Marlborough, and yet, as I was told, the flow of water in Hughie's Creek has not diminished in the least. My inspection of the creek confirmed this statement, for there was not the slightest indication of any lowering of the water-level.

The water of Hughie's and other springs on the Kaikoura Plain is derived mainly from the slopes of Mount Fyffe. It creeps through the gravels forming the various stream-fans until, probably through the influence of some clayey layer more or less impervious to water, it is forced to the surface. Quite possibly the bulk of the water forming each spring follows a fairly definite channel or course in the gravels in the early part as well as the later part of its career. There appears to be no danger of the springs being contaminated by surface drainage, but samples of the water, if it is to be used for a town supply, ought to be taken at different seasons of the year and subjected to analysis.

Hughie's Creek (excluding Lyell Creek, which is liable to contamination) is the nearest visible source of water-supply to the Township of Kaikoura. Possessing an ample and constant flow, the stream by reason of its origin in a spring is free from floods, and the only drawbacks that can be urged against its use are that the expense of bringing in the water will be somewhat great for the present small population, and that the pressure will hardly be sufficient to supply the hospital and other buildings on the higher levels, nor will it be adequate for fire-prevention purposes. Hence some pumping will have to be done, and ultimately a reservoir made to supply the high levels. For such a reservoir the hills of the Kaikoura Peninsula offer various suitable sites.

III. Possibility of Artesian Water on Kaikoura Plain.

The Kaikoura Plain has been formed by the coalescing of the delta-fans of the Kowhai and Hapuku rivers, with the addition of material transported by the small streams draining the seaward slopes of Mount Fyffe. Near the mountains it has a considerable slope, probably 100 ft. to the mile, but towards the sea its grade is 30 ft. or less to the mile. Theoretically the plain will be built up of numerous lenticular layers of gravel and finer debris, the coarser material predominating near the mountains and the finer towards the coast. Since remnants of ancient beaches on Kaikoura Peninsula and elsewhere along the coast prove considerable land-elevation in comparatively recent times, it follows that most of the debris transported by the streams was deposited by them in the sea, and hence is deltaic in character. The uppermost layers of the higher part towards the foot of the mountains were deposited on land, and are most correctly regarded as fan deposits.

A very large amount of water undoubtedly finds its way through the gravels and sands of the Kaikoura Plain to the sea, and the question to be considered is whether any of this water can be easily made available for a supply to Kaikoura Township. The conditions are similar to those of the Canterbury Plains and several other localities in New Zealand where artesian water is obtained. The analogy of Kaikoura with Christchurch is rendered curiously close by the presence of peninsulas—Banks and Kaikoura—both of which are formed of hard rocks, and were at one time islands. There appears to be no reason why bores for artesian water in the neighbourhood of Kaikoura should not be successful, provided sites some distance from the hills of the peninsula are selected, so as to avoid the danger of striking solid rock before a good water-bearing layer is tapped. It is also advisable, in the first place, to avoid boring near the shore-line in case brackish water only should be obtained. Experience, however, may ultimately show that fresh water extends right to the coast. Whether the water obtained by boring will rise well above the surface or fail to reach it cannot be predicted beforehand. Much depends upon the distribution of layers of clay or other comparatively impervious material in the neighbourhood of the bores. The most probable case is that the water will reach the surface, but without any great pressure behind it. In that event more or less pumping will be necessary.

Artesian Structure.—Even in some comparatively modern text-books the theory of artesian wells is treated in such a way that the reader will gather the impression that a basin structure is required. There are, however, at least half a dozen types of artesian structure, and of these the basin, as originally defined, is not the most important. It is a fact that in many situations, although the water of a porous stratum may have a means of escape, yet it will rise in a bore sunk to the porous stratum because the friction in the channels of escape provides considerable head available for forcing the water up the bore. Hence it is quite reasonable to expect that the underground water of the Kaikoura Plain can be successfully tapped by bores.

Conclusion.

Although my opinion need not be accepted as in any way authoritative, yet its expression may be of use in a discussion regarding the Kaikoura water-supply. Of the various possible schemes that of obtaining the town supply from Hughie's Creek seems on present information to be the best. As compared with the Luke's Creek or Waimangarara Stream proposals it has the advantage of being less expensive, but the disadvantage of not being purely gravitational. The installation of a pumping plant and the construction of a small reservoir on the Kaikoura Peninsula would make the Hughie's Creek scheme equal in every respect to any of the gravitation schemes, and probably at a smaller total cost. Bores for artesian water may be successful in obtaining water that can be delivered in the town at a slightly smaller cost than the Hughie's Creek scheme, but the supply from the latter is certain, whilst that from bores, though probable, is unproved not only as regards quantity, but as regards quality and pressure at the surface. It is not to be denied, however, that one or two trial bores seem to be fully justified by circumstances, and these, if thoroughly successful, would bring the claims of an artesian supply to the front.

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6. SOFT-LIMESTONE DEPOSITS OF CAPE CAMPBELL, WARD, AND WAIKARI DISTRICTS.

(By P. G. Morgan.)

Introduction.

Of late years attention has been directed to the value of ground unburnt limestone for agricultural purposes. In this connection Mr. B. C. Aston, Chief Chemist to the Agricultural Department, has pointed out that in New Zealand there are deposits of soft limestone which can be easily mined, and are in some cases suitable for spreading on the land without any preliminary treatment other than separating a small proportion of lumps by sieving. The known soft or friable limestone deposits of New Zealand can be classified under the following headings:—

(1.) Naturally extremely soft limestones in place, unmodified by faulting or similar agency. A typical example of this class is the calcareous ooze near Lake Hayes, Wakatipu district, described by Professor Park in N.Z. Geological Survey Bulletin No. 7.*

(2.) Friable limestones which on being quarried in the ordinary way yield a large amount of fine material, and of which the lumps can be very easily crushed, such as the Oamaru and Mauriceville limestones.

(3.) Fault-crushed bands in hard limestone.

(4.) Slope deposits of friable limestone derived from classes (2) and (3), and perhaps also produced by a peculiar weathering of hard or fairly hard limestone.

(5.) Calcareous travertine deposited by springs. This material may be regarded as a variety of class (2).

With this introduction the observations recently (December, 1915) made by the writer in Marlborough and North Canterbury may be given under the headings of (I) Cape Campbell District, (II) Ward District, and (III) Waikari District.

I. Cape Campbell District.

A belt of "Amuri" limestone† extends southward from a point on the coast-line between Lake Grassmere and Clifford Bay, and as viewed from the western side of Fisherman Creek valley appears to run out to sea several miles to the south. This belt of limestone is fault-involved, and in places has been so crushed that the naturally hard rock is reduced to a soft white chalky powder, containing only a small proportion of hard lumps. Outcrops of this material may be distinguished from a distance by their general appearance, and more especially by their peculiarly white colour. So far as can be seen, the quantity of crushed limestone is very large, and its quality fair. The facilities for mining are good, but this is hardly the case as regards transport, unless a large, steady demand should arise, in which event the construction of a tram-line would be advisable. The outcrops visited by the writer are approximately four miles from the railroad as the crow flies, and probably 400 ft. or 500 ft. above sea-level. The following analyses represent (1) an air-dried sample selected by the writer from an outcrop on the western side of Fisherman Creek valley, and (2) hard limestone from the coast-line between Cape Campbell and Lake Grassmere:—

	(1.)	(2.)
Insoluble in acid (silica, &c.)	27·43	17·03
Alumina and iron oxide (Al_2O_3, Fe_2O_3)	1·64	1·19
Lime (CaO)	36·92	44·12
Magnesia (MgO)	0·22	0·16
Carbonic anhydride (CO_2)	27·60	33·28
Moisture and organic matter	6·06	3·93
Phosphoric anhydride (P_2O_5)	0·14	0·13
	100·01	99·84

Mr. B. C. Aston, Chief Chemist, Agricultural Department, who visited the district shortly after the writer, obtained a sample of soft limestone from a spot on Mr. Cumming Law's property, known locally as the "Giant Shirt," and has kindly communicated the analysis, which shows 20·37 per cent. of insoluble matter, 2·37 per cent. of alumina and iron oxide, 73·68 per cent. of carbonate of lime, and 2·10 per cent of water.

II. Ward District.

Deposits of soft limestone have lately been discovered on Mr. A. Thomson's property by the owner and Mr. A. McTaggart, of the Agricultural Department. The locality is on the north side of the Flaxbourne River, near the road, and less than two miles from Ward Railway-station.

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* "The Geology of the Queenstown Subdivision," 1909, pp. 97–99.

† So called from the Amuri Bluff district, where this limestone is typically developed.

A cursory examination by the writer led to the belief that the deposits represent a band or bands of fault-crushed Amuri limestone. They may, however, in reality consist of slope debris detached from the solid limestone outcrops by erosional agencies and reduced to a powdery condition by some peculiar process of decomposition. The material at the outcrop inspected by the writer is a light-pinkish to light grey-and-white substance, which crumbles easily between the fingers, and is mixed with a moderate proportion of hard pieces of limestone, most of which are of small size. The analysis of an air-dried sample taken by the writer is as follows:—

Insoluble in acid (silica, &c.)	36·33
Alumina and iron oxide (Al_2O_3, Fe_2O_3)	2·77
Lime (CaO)	32·13
Magnesia (MgO)	0·35
Carbonic anhydride (CO_2)	23·82
Moisture and organic matter	4·57
Phosphoric anhydride (P_2O_5)	0·11
	100·08

Mr. B. C. Aston has communicated to the writer the results of analyses of numerous samples taken by himself and Mr. Thomson. These show that the carbonate of lime in the soft limestone varies from 45·82 to 76·42 per cent., whilst the hard limestone contains from 60·39 to 92·5 per cent. of carbonate of lime.

It is understood that Mr. Thomson intends to work the soft-limestone deposits on his land, and as a preliminary to drive into the one nearest the road, so as to get a better idea of the quantity and quality of the material than is at present possible.

III. Waikari District.

In the *Journal of Agriculture* for November, 1915, Mr. A. McTaggart interestingly describes the discovery of soft-limestone deposits near Waikari, and gives some details regarding their situation, quality, &c. The depth of these deposits, according to Mr. McTaggart, is in places at least 14 ft., but he gives no figures from which the average depth or the area covered can be calculated, and hence his opinion that there are probably "millions of tons or unlimited supplies of this desirable material in the locality" requires support before it can be accepted. As a matter of fact data for a reliable estimate of quantity and quality have not yet been obtained.

At the foot of a slope capped by limestone, and only a few chains south of Waikari Railway-station, is the spot where, as mentioned by Mr. McTaggart, the Waipara County Council has commenced to work a soft-limestone deposit. From the opening made, which is on the side of the road, over 100 tons of material has been excavated for experimental purposes. This has been roughly sieved on the spot, and part taken by the Agricultural Department, whilst the remainder has been distributed in small lots to settlers in various parts of Canterbury and Otago. The working-face shows the following section:—

9 in. black soil.
6 in. to 2 ft. hard limestone debris.
5 ft. to 7 ft. highly friable limestone debris mixed with hard fragments of various sizes.
Yellowish-grey sand.

The lower part of the friable material is clearly poorer in quality than the upper. Post-holes show that it extends at least 2 chains up the slope to the south, but it is not visible a few chains to the eastward, where a cutting on the south side of the road shows only yellowish sandy debris containing small irregular veins or patches of pure-white almost impalpably fine material resembling whiting.

The writer also visited the property of Mr. H. H. Holland, situated about two miles west of Waikari. This gentleman, who has taken a great interest in the question of obtaining supplies of lime or limestone for agricultural purposes, kindly showed the writer the soft-limestone deposits on his land and on the education reserve (Section 1145) about a mile to the east. Mr. Holland's deposits are on the slopes of a limestone-capped hill south-west and west of his residence, and apparently extend over a considerable area. They are overlain by a foot or two of soil, and in one place have been bored to a depth of 14 ft. A number of shallow test-pits have also been dug, with the result that the quality of the limestone is shown to be somewhat variable. Half a mile or so to the west of Mr. Holland's house a pit, which remains open, shows only 2 ft. of soft-limestone debris (of good quality, however), underlain by hard rock.

The soft-limestone deposit on the education reserve is near the foot of a slope below a limestone ridge. This has been bored to a depth of 14 ft., but only at one place, so far as the writer could learn.

Elsewhere in the Waikari district are various accumulations of soft limestone, as mentioned by Mr. McTaggart in his article. None of these has been seen by the writer except a small deposit which is exposed by a railway-cutting in Weka Pass.

The following partial analyses of soft limestones are quoted from Mr. B. C. Aston's article, "South Island Limestone Analyses," in the *Journal of Agriculture* for October, 1915, and from Mr. McTaggart's article previously cited. The publication of the complete analyses and of the exact localities of the samples may be urged as a desirable step.

Locality.	Calcium Carbonate ($CaCO_3$) per Cent.	Moisture, &c., per Cent.	$CaCO_3$ on Moisture-free Basis.	Remarks.
(1) Weka Pass Road, Waikari	72·92	..	..	
(2) Waikari ..	71·31	18·47	87·46	
(3) Waikari ..	60·82	19·60	75·65	
(4) Waikari ..	69·50	..	..	
(5) Waikari ..	43·30	..	..	Sample from 8 ft. to 14 ft. below surface.
(6) Waikari ..	69·70	..	..	Sample from depth of 6 ft. below surface.
(7) Waikari ..	59·00	..	..	Sample from 8 ft. to 14 ft. below surface.
(8) Waikari ..	93·00	..	..	
Mr. H. H. Holland's property	..	..	About 88	

Origin of Soft-limestone Deposits.

The classification of soft-limestone deposits given in the introductory paragraph indicates in a general way the modes in which they originate. It will readily be understood that soft material does not afford good outcrops, and that until considerable openings have been made the origin of any given deposit may be more or less doubtful. Thus, as regards the Waikari deposits, it is clear that as exposed they are accumulations of limestone debris on slopes below limestone outcrops, but it is not clear whether the material has come from fault-crushed bands in the rock, or has been formed by the weathering of hard limestone. It is perhaps as well to emphasize the fact that the Waikari deposits are slope accumulations, of comparatively modern date, derived from limestones of Early Tertiary or Late Cretaceous age, and not bedded portions of those limestones, as has been suggested by one or two of those who have seen the deposits. Thus it becomes evident that their composition is likely to vary greatly, a fact that is indeed shown by the analyses quoted.

Quality and Quantity of Soft Limestone.

The soft-limestone deposits described in this report belong to two classes—fault-crushed material approximately in place, and detrital accumulations on or at the foot of slopes. The material of fault-crushed bands may be expected to have much the same composition on a moisture-free basis as the hard limestone with which it is associated. Detrital accumulations, owing to the inclusion of clay and other foreign substances, on the whole must be regarded as less pure than the original limestone, but it seems to be a fact that in places, as mentioned above, some concentration of calcium carbonate has occurred. Such an enrichment, however, will seldom or never apply to the whole thickness of the deposit. There need be little doubt, however, that considerable portions of the various deposits are sufficiently high in calcium carbonate to be of value for agricultural purposes. The fact that as mined or dug the soft limestone will contain a high percentage of moisture needs to be clearly stated. In summer the greater part of this can be expelled by air-drying, but if the deposits are to be worked in winter artificial drying will probably be found necessary.

Although the quantity of friable limestone in the Cape Campbell, Ward, and Waikari districts is no doubt large, yet a considerable amount of exploration is required before any authoritative statement can be made. In estimating quantity, geological investigations of the origin and mode of occurrence will be helpful, but, above all, numerous test-pits, bores, and measurements of area are imperative. This last statement applies more particularly to slope accumulations, which are highly variable, both in thickness and quality. Finally, the grade of material worth transporting long distances must be determined by analysis.

7. NOTES OF A VISIT TO MARLBOROUGH AND NORTH CANTERBURY, WITH ESPECIAL REFERENCE TO UNCONFORMITIES POST-DATING THE AMURI LIMESTONES.

(By P. G. Morgan.)

Introductory.

The writer left Wellington for Picton and Blenheim on the 13th December, 1915, and next day proceeded to Ward (Flaxbourne), where two days were spent in the examination of the country within reach. On the 17th December he went to Kaikoura, where he remained for several days. The 22nd and 23rd December were occupied in examining the neighbourhood of Hundalee, the lower Conway River, and Amuri Bluff. On the 24th the writer proceeded to Waipara, and employed the next four days in visits to Weka Pass, Waikari, the middle Waipara Gorge, Cass Range, &c.

Cape Campbell-Ward District.

The country between Cape Campbell and the Flaxbourne River was superficially examined by Hutton in 1873 (4*, p. 27), and in somewhat greater detail by McKay several years later (7, pp. 185–91). Subsequent visits by geologists have been of very brief duration. Although McKay's later reports contain some additional information, the geology of the district is far from being sufficiently elucidated. The rocks present, according to McKay, range in age from Cretaceous to Pliocene, and consist of igneous breccia, sandstone, limestone, mudstone, conglomerate, &c. By adding Pleistocene and Recent deposits the following classification is reached :—

Formation or Series.	Composition, &c.	Approximate Age.
——	Gravels, &c., of river-flats, terraces, and raised beaches	Recent and Pleistocene.
Great Marlborough Conglomerate ..	Conglomerate east of Lake Grassmere ..	Pliocene (?).
Awatere beds	Calcareous mudstone, &c.	Miocene.
Grey Marl	Calcareous mudstone and fine sandstone ..	Early Tertiary (?).
Waipara	Limestone, flint, sandstone, igneous breccia, conglomerate, &c.	Cretaceous (possibly in part Early Tertiary).

For many details concerning the various rock formations the reader may be referred to McKay's reports. His sketch-map published in 1877 requires considerable corrections, but in order to make these a detailed survey is necessary. The following remarks, supplementing McKay's information, may here be given. The Flaxbourne breccia does not consist wholly of fragments of igneous origin, but also contains a considerable proportion of sedimentary rocks. Much of the material is water-worn, and there are small bands of dark-grey mudstone interbedded with the coarser beds.† Calcite is abundant in vesicles of volcanic rock fragments, as a cement, and as lenticular patches. In places the calcareous material is decidedly phosphatic. These observations confirm a verbal statement made by Dr. J. A. Thomson to the writer that the breccia probably passes northward into an ordinary conglomerate. It occupies a much narrower area than that shown on McKay's map, for its western boundary is some distance east of Lake Elterwater.‡

The limestone of the Cape Campbell - Ward district, together with the flinty concretions and lenses in which it abounds, may conveniently be hereafter referred to as the Amuri limestone, the name in common use for this portion of the Waipara Series. Owing to the combined effects of faulting and folding it has a more erratic distribution than that shown on McKay's map. In particular a belt of flinty facies trends along the coast north and south of the Flaxbourne River. Appearances favour the opinion that there are two distinct bands of limestone, separated by a thick bed of sandstone, but further examination is necessary before this view can be established. The interstratified greensand beds mentioned by McKay (7, p. 188) are of small thickness. They are best seen at the outcrop of Amuri limestone on the shore east of Lake Grassmere, where, however, owing to faulting, only the uppermost limestone horizon is represented.

The calcareous grey mudstone, or in places fine sandstone, known as the Grey Marl, has a great development in the Cape Campbell district. It forms cliffs from the Amuri limestone outcrop mentioned above to Cape Campbell, and thence southward along the coast. Since the breadth of exposure at right angles to the strike is almost three miles, and the dip in most places is 40° or over in a consistent easterly or south-easterly direction, McKay's estimated thickness of 8,000 ft.§ (7, p. 189) seems reasonable, provided there is no fault in the section. Faults, however, are present, and though their effect cannot be definitely stated, a considerable reduction of McKay's estimate may be safely made. Another factor that may enter into the question is the possible presence of Awatere beds in the upper part of the supposed Grey Marl section.

The Awatere beds of the district lithologically resemble the Grey Marl, and can be certainly separated from it only by their fossil contents. They are less indurated than the average sample of Grey Marl, and consequently even more liable to slump. The greater part of their eastern boundary as shown on McKay's map of 1877 ought to be extended farther to the east, particularly in the neighbourhood of Lake Elterwater.

The Great Marlborough or post-Awatere Conglomerate was found by the writer to occur between Lake Grassmere‖ and Cape Campbell near the position indicated by McKay, but somewhat farther to the eastward. The exposure is much narrower than shown by McKay's map of 1877, and probably does not extend so far to the south. His map of 1890 (16, opp. p. 96), though on a much smaller scale, is more correct in these respects. The character of the conglomerate, except that no boulders over 2 ft. in diameter were seen by the writer, is precisely as described by McKay, and his estimated thickness of not less than 200 ft. is approximately correct, or, at least, not over the mark. Curiously enough, in 1877 McKay, as shown by his section BB (7, opp. p. 188), misjudged the stratigraphical relations of the conglomerate, so that his estimate of the thickness must have been a mere guess. Instead of lying on the upturned edges of the other formations, it is involved equally with them in a great fault-zone, and has an almost vertical

* This and other numbers similarly enclosed in parentheses refer to the list of literature at end of report.
† McKay mentions interstratified beds of green sandstone (7, p. 187).
‡ In December, 1915, Lake Elterwater was perfectly dry.
§ In Sixth Ann. Rep. G.S., C.-9, 1912, p. 9, this estimate is misquoted as 12,000 ft.
‖ Lake Grassmere was dry at the time of the writer's visit in December, 1915, although its bed is below high-water mark.

dip inclining to the south of east. It is thus similar in attitude to the Awatere beds lying immediately to the west, and to the Amuri limestone seen not far to the east. Since it must actually, as well as seemingly, overlie the Awatere beds,* it cannot be conformable to the Grey Marl, as supposed by Cotton (24, p. 245; 25, p. 350 *et seq.*), and Thomson (23, p. 123), unless the Awatere beds and the Grey Marl are strictly contemporaneous, an hypothesis which, notwithstanding the lithological similarity, no one has yet been bold enough explicitly to state, though it certainly seems to be logically deducible from the views held by Marshall (see 19, 20, 21) and by Cotton (24, 25).

Evidence of raised beaches in the form of well-worn shingly pebbles may be observed on the seaward slopes north of the Flaxbourne River. The projection forming Cape Campbell is flat-topped, and is clearly a fragment of a sea-worn terrace formed when the land was roughly 200 ft. below its present level. Remnants of a relatively modern beach, only a few feet above high-water mark, may be seen here and there along the coast-line. They are especially well preserved between Lake Grassmere and Cape Campbell.

Faults.

The hilly country extending north-north-east and south-south-west from Ward is badly smashed by faults trending north and south or somewhat east of north. The western boundary of the Cretaceous rocks is formed by a great fracture which represents, in whole or in part, the northern extension of the "Great Clarence Fault" of McKay (17, pp. 14–18). Involved in this fault or fault-zone are not only the outcrops of the Great Marlborough Conglomerate east of Lake Grassmere, but also those farther south described by Cotton as conformable to the Grey Marl (25, pp. 350 *et seq.*). Faults usually detract from the value of the mineral deposits they intersect, but the crushing of the Amuri limestone where it is traversed by faults has increased its usefulness for agricultural purposes by providing a great amount of naturally comminuted material. (See Special Report No. 6, p. 15.)

Economic Geology.

Limestone.—The Amuri limestone, though as a rule somewhat siliceous, and in its lowest horizon largely replaced by flint, can furnish lime for agricultural purposes in practically inexhaustible quantity. Lately a proposal to use ground limestone in the Marlborough District has been made, but since the Amuri limestone in its normal condition is an exceedingly close-grained and hard rock, it needs grinding to a fine powder, necessarily a somewhat expensive process. The discovery of the soft-limestone deposits described in another report (see p. 15) will therefore probably be of great value to the neighbouring districts.

Phosphate.—Many years ago a white mineral taken from a cave near Flaxbourne (Ward) and forwarded to the Colonial Laboratory was found to be mainly a hydrous phosphate of aluminium, with some ammonium phosphate, and contained 31·64 per cent. of phosphoric pentoxide (Twenty-seventh Ann. Rep. of the Col. Mus. and Lab., 1893, p. 27). Probably this sample came from the sea-coast, and represented merely a minor modern deposit formed by the interaction of guano and some aluminous substance. The phosphatic horizon immediately overlying the Amuri limestone at Kaikoura, Amuri Bluff, and Weka Pass appears not to be present in the Cape Campbell - Ward district. The limestone itself, as would be expected from its lack of organic remains other than those of low type, such as Foraminifera, is exceedingly low in phosphatic content, as was determined by a number of qualitative tests. Various other rocks were tested for phosphate with practically negative results, but a small sample of calcareous fine-grained Flaxbourne breccia yielded a good test, and was therefore analysed, with the result that it was found to contain 0·90 per cent. of phosphoric anhydride, equivalent to 1·96 per cent. of tricalcic phosphate.

Kaikoura District.

The Kaikoura district has been visited at various times since 1872† by Hutton, Hector, McKay, and other geologists, but only those named have published anything of importance relating to the neighbourhood of Kaikoura Township. Concerning the geology of Kaikoura Peninsula a sharp difference of opinion arose between Hutton on the one hand and Hector, supported by McKay, on the other. The principal point in dispute was whether a physical unconformity separated the Amuri limestone from the overlying Grey Marl. The present writer paid special attention to this matter, with the result that he is able in some measure to confirm Hutton's view, and to state that what appears to be a mild local unconformity intervenes between the Grey Marl and the underlying limestone. Moreover, there is a second and stronger unconformity in the limestone at an horizon, roughly, from 50 ft. to 120 ft. or more below the Grey Marl contact. The same unconformity appears at and near Amuri Bluff from 15 ft. to 50 ft. below the Grey Marl, and is also observable far to the south in the Waipara-Waikari district, as stated in a later part of this report.

Physiography.

The Seaward Kaikoura or Looker-on Range, with a trend parallel to the coast, forms the dominating physical feature of the Kaikoura district. It reaches heights well over 8,000 ft., but as viewed from Kaikoura Township the most prominent elevation is Mount Fyffe (Kaitarau).

* This statement may not be valid if important fault-movement has taken place between the Awatere beds and the conglomerate. This, however, does not seem to be the case.

† The earliest report is by John Buchanan. See Abstract Report on the Progress of the Geol. Surv. during 1866–67, No. 4, 1868, pp. 34–41.

with a height of 5,260 ft. North of the Hapuku River and south of the Kahutara, spurs of the Looker-on Range reach the shore, but the greater part of the area between these points is a fertile delta-fan,* built mainly by the Kowhai and Hapuku rivers. This plain has a considerable upward slope to the base of the mountains, the grade, of course, increasing as the high land is approached. Its outer margin is interrupted by the moderately low smooth hills that form Kaikoura Peninsula. These, on the seaward sides of the peninsula, terminate in cliffs descending to high-water mark or to low raised beaches. Several stacks and numerous outlying rocks, with tops at or above high-tide level, mark comparatively recent encroachment of the sea upon the peninsula, a process contemporary with the outbuilding of the Kaikoura Plain by the rivers.

Considerable elevation of the land in not very remote periods is shown by the presence of numerous wave-cut platforms on the peninsula. These may be traced to the highest points (450 ft. or more), and are especially well marked at levels of approximately 100 ft. and 160 ft., where also fine beach-shingle is present. The 100 ft. stage is well represented north of the Hapuku River by a fluvio-marine terrace. The most modern period of standstill is distinguished by raised beaches a few feet above high-water mark on the north and south sides of Kaikoura Peninsula, which continue along the seaward margin of the Kaikoura Plain, and by sea-worn caves 10 ft. or 12 ft. above high-tide level on its eastern side. The long straggling township of Kaikoura is built mainly on strips of raised beach flanking the northern coast of the peninsula. Especially noteworthy is the magnificent raised storm-beach, with crest 6 or 7 chains wide, that extends for nearly two miles northward from the mouth of Lyell Creek. Low sandhills, backed by a small terrace, then take its place. Extensive rock benches or shelves, with a very slight downward slope from high-water mark, are developed on the eastern and southern sides of the peninsula, and constitute additional evidence of the encroachment of the sea upon its solid flanks of comparatively hard rock. Similar shelves are seen on many other portions of the New Zealand coast, but have not received much attention in the geological literature.†

The principal streams of the Kaikoura district are the Hapuku (with its tributary the Puhipuhi), the Kowhai, and the Kahutara. These streams, especially the Hapuku and the Kowhai, fed with abundant debris from the crumbling rocks of the Seaward Kaikoura Mountains, have built great delta-fans, which by their coalescence form the Kaikoura Plain. Noteworthy are the large blocks, some 6 ft. in diameter, brought by the Hapuku River to its fan, thus causing the material to resemble morainic or fluvio-glacial gravel, a feature noted by McKay in 1890 (16, p. 183). Though the three streams named above carry large bodies of water in time of flood, yet during dry seasons such as that prevailing at the end of 1915 their visible flow is reduced to a few cubic feet per second. There need be no doubt, however, that the water escaping by percolation through the gravels of the various fans greatly exceeds that seen in the stream-channels.

The valley of the Puhipuhi River, as seen from the neighbourhood of Kaikoura, is remarkably straight, and almost typically U-shaped in cross-section. Thus glaciation is inevitably suggested, but the features noted are clearly related to structural causes, with some modification due to stream-erosion. The neighbouring valley of Irongate Creek presents similar characters.

No physiographic account of the Kaikoura district could be written without some description of the faults that dislocate all the rocks except those of Quaternary age, and it is doubtful if even these latter have entirely escaped. A tremendous fault or fault-zone, the Kaikoura fault of McKay (16, p. 98; 17, pp. 12–14), marks the eastern base of Mount Fyffe, and evidently extends far to the south-west into the Cherwell Valley. North-eastward it passes up the Puhipuhi Valley and, crossing a saddle, enters the lower Clarence Valley. Thence, according to McKay, it reaches the mouth of the Flags River, and, crossing Cook Strait, extends up the Wairarapa Valley along the eastern base of the Rimutaka Range. McKay remarks that "between the lower Clarence and the eastern base of Mount Fyffe, west of Kaikoura Peninsula, the fault-line is single." But this is doubtful, for a parallel dislocation probably extends through the upper part of Irongate Creek valley, and there is certainly strong parallel faulting along the coast-line, as shown by the smashing and crushing of the pre-Quaternary rocks wherever these are exposed. Thus the essentially faulted nature of the coast-line is clearly demonstrated. This feature, which forms part of the subject-matter of an elaborate paper by Cotton,‡ was somewhat crudely described by J. Buchanan (1, p. 36) almost half a century ago.

The much-disturbed rocks of Kaikoura Peninsula show several considerable faults with a north-east trend, approximately parallel to the strike of the fractured beds, besides a great number of minor dislocations. Several small faults may be seen traversing the rock bench near the eastern headland of the peninsula, whilst at a spot near the Maori settlement on the south side (South Beach) no less than fourteen faults may be seen dislocating the limestone and Grey Marl in a distance of less than 7 chains. These are small normal faults striking into the north-west quadrant, and in most cases dipping steeply to the south-west. Thus they are nearly at right angles to the strike of the dislocated rocks and to the major faults of the district. A sketch showing a number of these faults is given by McKay in one of his reports (13, p. 76).

General Geology.

Although a fairly comprehensive idea of the geology of the Kaikoura district can be obtained by studying McKay's reports (6, 11, 13, 16), yet a recapitulation of the main points may be useful to the reader. The oldest rocks of this part of New Zealand are the strongly-folded much-

* See page 14 for explanation of this term.

† See, however, J. M. Bell and E. de C. Clarke in "The Geology of the Whangaroa Subdivision." N.Z.G.S. Bull. No. 8, 1909, p. 30, for a careful discussion of rock-benches on the shores of the Whangaroa Subdivision. See also a short paper by J. A. Bartrum, which will appear in the 1916 volume of the Trans. N.Z. Inst.

‡ Cotton, C. A.: "Fault Coasts in New Zealand," the *Geographical Review*, vol. i, No. 1, January, 1916, pp. 20–47.

disturbed greywackes and argillites forming the Seaward Kaikoura Range. These are regarded by McKay as belonging to the Maitai System, and therefore of Carboniferous age. Similar rocks occupy a considerable area near the coast north of the Hapuku River, appear in the lower part of the Puhipuhi Valley, and form hilly country south of the Kaikoura River. These, together with some badly weathered sandstones or greywacke occupying a small portion of Kaikoura Peninsula, are mapped by McKay as Liassic, whilst to lithologically similar rocks south of the Kahutara River he assigns a Triassic age. At the present time there is no satisfactory evidence to show that the rocks of the Seaward Kaikoura Range are older than those of similar appearance near the coast-line, and therefore all may well be tentatively assigned to a Trias-Jura system until the necessary criteria for subdivision are forthcoming.

Resting unconformably on the Trias-Jura rocks are sandstones and shales, reported by McKay (6, p. 176) to contain Inoceramus, and therefore presumably of Cretaceous age. These rocks, which are but poorly exposed either in the Kaikoura Peninsula or the Puhipuhi Valley, are succeeded, apparently with conformity, by the thick, fine-grained, hard limestone known to geologists as the Amuri limestone, the age of which is either Upper Cretaceous (Danian) or very early Tertiary. The upper limit of this must be regarded as defined by a water-worn surface, on which rests unconformably a thin layer of conglomerate formed almost wholly of phosphatized fragments of limestone, embedded in a calcareous glauconitic and sandy matrix, and accompanied by thin inconstant beds of greensand. Next follows from 50 ft. to 120 ft. (or more) of limestone, lithologically similar to the Amuri limestone, but considered by McKay to be equivalent to the Weka Pass stone of northern Canterbury (16, pp. 163–64), a correlation that seems to be well founded, and that, if accepted, implies a Tertiary age for the Kaikoura rock. Next in upward succession follows the Grey Marl, a calcareous argillaceous rock of great thickness, which, as previously stated, is separated by a mild unconformity from the underlying limestone. The Grey Marl in most localities contains a considerable amount of fine micaceous sand, so that the name given to it is not altogether a happy one. In places, especially towards its base, it is really a fine or even medium-grained calcareous sandstone. Small pyritic concretions, many now converted into limonite, are not uncommon in the exposed faces of Grey Marl east of the Maori village on the south side of Kaikoura Peninsula. On the tidal shelf in the same locality a number of steeply dipping veins of calcareous sandstone, none more than a foot in thickness, may be seen crossing the bedding of the Grey Marl at various angles. These are evidently of the same nature as the so-called "sandstone dykes" of California and other regions.

Notwithstanding the unconformities present, the post-Jurassic rocks of the last paragraph, whether Cretaceous or Tertiary, do not exhibit any marked divergence in structure other than the peculiar local corrugations of the limestone to be described later. In the Puhipuhi Valley, owing to the combined effects of folding and faulting, they strike north-north-east, and dip at high angles to the south of east or north of west. In Kaikoura Peninsula their strike is generally north-east and their dip of varying intensity. On the whole, as stated by McKay (6, p. 174) the arrangement appears to be anticlinal, but is complicated by minor crumpling and by faulting.

The remaining rocks of the district are of Pleistocene to Recent age, and consist in the main of the gravels forming the great conjoint delta-fan of the Hapuku, Kowhai, and Kahutara rivers, together with the shingle and sand that constitute the raised beaches described on a former page under the heading of "Physiography."

Geological Map.—McKay's geological maps being merely rough sketches on small scales, it is desirable that a more detailed map of the Kaikoura district should be published. Owing to the insufficiency of the available data, a geological map to accompany the present report could not be prepared, and it is evident that a considerable amount of survey is needed in order to enable one of a satisfactory nature to be compiled.

Minor Folds or Corrugations of Limestone.

The limestone of the Kaikoura Peninsula in places shows a remarkable corrugated structure not clearly traceable into the overlying Grey Marl. These corrugations were therefore considered by von Haast to be evidence of unconformity between the two rocks (2, p. 39, and section viii, opp. p. 46), whereas Hector, on the other hand, regarded them as produced in the limestone by some form of concretionary action (3, p. xi). At a later time he seems to have ascribed the phenomenon to dynamic forces only (12, p. x). The writer observed that on the east side of Kaikoura Peninsula the Grey Marl shows traces of minor folds in sympathy with the underlying contorted limestone, and, moreover, is slickensided close to the contact with the underlying rock. Hence it is clear that Hector was right as regards the minor significance of the local contortions in the limestone. Marshall, Speight, and Cotton's explanation of the reason why the corrugations are not seen in the Grey Marl—namely, that its plasticity allowed it to yield to external forces without itself being materially deformed (19, p. 390)—seems to be perfectly correct.

Highly irregular corrugations are seen on the tidal rock shelf at the east head of Kaikoura Peninsula, where they affect the uppermost layers of the limestone immediately below the Grey Marl. Being exposed by denudation over an area that may be measured in acres, they give an appearance comparable to a choppy sea. In the cliffs to the southward they are of greater size and appear somewhat more regular, but on the foreshore near the Maori village close irregular folds, with a vertical component of only a very few feet, are again prominent. Here the upper 60 ft. of the limestone adjoining the Grey Marl, though with a steep dip, is fairly regular. The contortions were not observed to extend in any exposure below the thin conglomerate that marks the contact with the true Amuri limestone, but it cannot be definitely stated that such is everywhere the case. McKay, indeed, gives a sketch showing corrugation in the older limestone (13, p. 76).

A few minor corrugations were seen by the writer in the steeply dipping limestone of the Puhipuhi Valley about four miles from the Hapuku River. Though Grey Marl appears not far away, the writer's notes are insufficient to enable him to say whether the corrugated rock forms part of the upper limestone (Weka Pass Stone horizon) or of the underlying Amuri limestone.

Marshall, Speight, and Cotton describe corrugation or puckering of the Amuri limestone at the mouth of Okariki (Okarahia) Stream, near Amuri South Bluff (19, p. 390), whilst von Haast and Hutton mention what appears to be similar corrugation of the Amuri limestone on the south bank of the Conway River, ten or twelve miles from its mouth (2, p. 40; 9, p. 271).

Unconformities.

References to the presence of two unconformities above the Amuri limestone have already been made, and the evidence for their existence will now be presented in detail. The lower of these unconformities, that separating the Amuri limestone proper from what may be called the upper limestone (horizon of Weka Pass stone) has apparently not previously been definitely recognized as a stratigraphical break.* The chief evidence in its favour is furnished by the water-worn and irregular upper surface of the Amuri limestone, similar to that at Weka Pass as described by Hutton (4, p. 44), and by the presence of the thin bed of phosphatized limestone conglomerate previously mentioned. The pebbles of this rock weather externally to a dark-greenish hue, and as a rule their interior is also more or less greenish in colour. This peculiarity explains Hector's description of the bed in question as "a thin layer of brecciated fragments of calcareous greensands" (3, p. xi). Thus he does not recognize it as a conglomerate or as evidence of unconformity, and in this is followed by McKay. Hutton speaks of bands† of conglomerate interbedded with the Amuri limestone at Kaikoura (4, p. 39), but, curiously enough, does not suspect the existence of a stratigraphical hiatus. Owing to the presence of phosphate in the horizon under discussion, the question of unconformity has direct economic as well as scientific importance, and therefore a full summary of the writer's notes respecting the contact between the Amuri and the upper limestone will be given.

Immediately east of the Maori village on the south side of Kaikoura Peninsula a considerable exposure of limestone above high-water mark is visible. Here the conglomerate layer, which will be found some chains west of the Grey Marl outcrop, is 6 in. thick, and consists mainly of subangular pieces of phosphatic limestone, with an average diameter of 1 in. or a little more. The rock above is white flaggy limestone, that below is a greyish-white argillaceous limestone, the uppermost layer of which is crowded with "fucoid" casts. There is no detectable discordance in the bedding-planes of the over- and the under-lying rock. In the cliff a few chains to the north the conglomerate, here about 5 in. thick, may be found after a little search in a horizon roughly 120 ft. or 130 ft. below the Grey Marl.

On following the shore-line eastward from the Maori village the conglomerate is next seen about a mile away at the base of a small headland north-east of Atui Point, where it is 6 in. to 9 in. thick. Here it is underlain by 6 in. of limestone containing a few scattered pebbles of calcareous rock and some small irregular lenses of sandstone, which appear to represent worm-casts. Below this is a band of limestone, barely 1 ft. thick, which also contains cylindrical worm-casts approaching in their character so-called fucoid casts. Above the conglomerate is 2 in. to 3 in. greensand, followed by some feet of more or less glauconitic limestone containing a few pebbles of the same kind of rock (probably somewhat phosphatized). The conglomerate itself consists of small subangular to rounded calcareous pebbles with greenish exterior, embedded in a matrix of calcareous green sand. Its strongly phosphatic character is shown by the following part analysis: Calcium carbonate ($CaCO_3$), 34·95 per cent; phosphoric anhydride (P_2O_5) 24·55 per cent. The phosphoric anhydride is equivalent to 53·62 per cent. of tricalcic phosphate.

The phosphatic conglomerate can be traced some distance along the cliff to the north-east in a horizon 60 ft. to 70 ft. below the Grey Marl. At one point in the cliff 2 ft. of greensand with interlaminated limestone overlies, but more to the north-east this almost completely disappears. As viewed from a little distance the limestone above and below it are very much alike. Owing to faulting the conglomerate a little to the northward is raised to a horizon above the cliff-top, and therefore cannot be seen for some distance, but is again visible at a small headland not far from the east head of the peninsula. Here it is 9 in. thick, and overlain by 2 in. or 3 in. of greensand, above which comes 50 ft. or 60 ft. of limestone and then the Grey Marl.

The contact between the upper limestone and the Grey Marl is in several respects very similar to that just described. It may best be seen on the rock shelves at the east head of the peninsula and near the Maori settlement. In both localities there is a sharp passage from limestone to a calcareous grey sandstone, which in places near the contact is somewhat coarse-grained. On the whole the sandstone has been deposited parallel to the bedding-planes of the limestone, and therefore there is apparent conformity. As explained previously, the discrepancy produced by local corrugation of the limestone has no bearing on the question of unconformity, but at one spot near the Maori village there is apparently a very slight angular unconformity, which, owing to faulting, cannot be clearly traced for more than a few yards.

Viewed closely, the upper surface of the limestone is highly irregular and covered with small erosion hollows, now tightly filled by the overlying calcareous sandstone, which, coloured somewhat by glauconite, also penetrates into small irregular passages and fissures in the limestone. Many of the smaller passages are undoubtedly worm-borings, but owing to extensive reboring in modern times and just prior to the last minor uplift of the land this is not so prominent as it would otherwise be. At one or two places the limestone close to the contact is

* Hutton's unconformity in the Kaikoura Peninsula is at the base of the Grey Marl (see *postea*).
† There is, however, only one conglomerate horizon in the limestone.

glauconitic, thus apparently showing a transition into glauconitic Grey Marl, but since its lowest horizon is also glauconitic not much importance need be attached to this feature. Other characters somewhat favouring a transition without unconformity are the presence of thin sandstone layers in the upper part of the limestone, and, at one or two places only, an apparent interlamination of sandstone and limestone at the contact. This last phenomenon may be explained as due to chemical erosion of the limestone along bedding-planes, followed by deposition of sand in the cavities.

The Grey Marl (sandstone) in the first foot above the contact contains a few irregularly shaped "floaters" and sub-rounded pebbles of light-coloured limestone, together with very rare pebbles or fragments of sandstone lithologically similar to the lowest horizon of the Grey Marl itself. There are also some rounded pebbles, with dark exterior but lighter-colored greenish interior, which are usually of very small size, and in most cases are probably phosphatized limestone, but some may possibly be greywacke. These are found extending several feet above the limestone contact. Near the Maori village the Grey Marl sandstone contains a few water-worn pieces of dark-brown bone, probably derived from the skeleton of a ziphioid whale or allied animal. A saurian origin, however, is possible, and if it could be proved would be clear evidence in favour of unconformity. McKay also refers to the occurrence of bone fragments in the Grey Marl (13, p. 77).

In the Puhipuhi Valley definite evidence of the unconformities described above could not be obtained in the time available for examination. About four miles up the valley the Amuri limestone gives place to thin inconstant beds of greensand containing a few fish-teeth, followed by hard bluish calcareous sandstone. This last rock passes into more or less typical Grey Marl—that is, into bluish calcareous and argillaceous fine-grained sandstone.

Economic Geology.

Limestone.—The upper part of the Amuri limestone and the overlying upper limestone, though somewhat arenaceous, may be used for the production of quicklime, and are also more or less suitable for use as building-stones. At the end of 1915 a small plant at the east end of Kaikoura Township was producing ground limestone for agricultural purposes. The lower part of the Amuri limestone is too flinty to be of much value.

Phosphate.—The analysis of the phosphatic conglomerate marking the unconformity between the Amuri limestone proper and the upper limestone quoted on a former page shows that at the locality where the sample was taken it contains 53·62 per cent. of tricalcic phosphate, which, though low-grade, marks a commercially saleable quality. The only previous record of phosphate from the vicinity of Kaikoura is in the "Thirty-second Annual Report of the Colonial Laboratory" (1899, p. 9), where it is stated that a "nodule of impure coprolites" containing some quartz pebbles, forwarded by Messrs. Thompson and Co., per Mr. R. C. Renner, of Kaikoura, contained 16·14 per cent. of phosphoric anhydride (equivalent to 35·24 per cent. of tricalcic phosphate). McKay in his report of 1890 refers to the presence of a "phosphatic or concretionary greensand bed" (16, p. 164) underlying calcareous sandstone (the upper limestone of this report).

The exposures of phosphatic conglomerate on the shores of Kaikoura Peninsula are more likely to contain less than 50 per cent. of calcium phosphate than a greater percentage, but proof of this has yet to be obtained by means of a series of analyses. Moreover, the known outcrops, which range from only 5 in. to 9 in. in thickness, are too thin to be worked to any great extent, but the proving of a definite phosphatic horizon is of importance, since it furnishes a clear guide for prospecting not only at Kaikoura Peninsula, but also in neighbouring districts, such as the Puhipuhi Valley, Amuri Bluff (see *postea*), Conway River, Gore Bay (Port Robinson),* &c.

Oil-indications.—An inflammable-gas emanation reported to occur in the Puhipuhi district is naturally regarded as an indication of petroleum. Though on the whole the available geological data are not favourable to this hope (as regards the Puhipuhi Valley), yet the occurrence, taken in conjunction with the gas and oil springs farther north in the Ure River (Benmore) district (see 27, pp. 100–1), and the oil-seepages near Cheviot, has some value as an indication of the possible petroliferous character of the Cretaceous rocks in other localities where better conditions prevail. It may be noted that in a very early report J. Buchanan (1, p. 38) mentions the supposed occurrences of occasional films of oil on the sea off "Squally Point," a name not shown on any map known to the writer.

Miscellaneous.—McKay mentions that some years previous to 1890 a "reef" was discovered on Mount Fyffe, near Kaikoura, which contained traces of gold (16, p. 138), and adds the very doubtful statement that a quantity sent to Australia was reported to have yielded something like 2 oz. gold to the ton. The only other record known to the writer of any commercially valuable metallic mineral being found in the Kaikoura district will be found in the "Twenty-first Annual Report of the Colonial Museum and Laboratory," 1886, p. 47, which mentions stibnite, with about 20 per cent. of antimony, collected from the Puhipuhi ("Buibui") Valley. In the Thirtieth Annual Report, 1897, p. 13, are two analyses of epsomite from Kaikoura.

Amuri Bluff, Hundalee, Conway River, etc.

On the 22nd and 23rd December the writer had an opportunity of examining the coast-line from the mouth of the Conway River to that of Oaro Stream, and the inland country to the

* Von Haast mentions a "peculiar greensand conglomerate about 3 ft. thick" at Gore Bay (2, p. 41). McKay's reports contain frequent references to the same horizon.

west traversed by the main road. The most important observations made relate to the raised beaches near the coast-line, to some beds, mainly conglomerate, of Upper Tertiary age, and to an unconformity above the Amuri limestone similar to that already described as occurring in the neighbourhood of Kaikoura. The general geology of the localities now under consideration is practically the same as that of the Kaikoura district.

Raised Beaches.

Evidence of considerable elevation in Pleistocene and Recent time is very easily observed almost everywhere along the Marlborough coast. At the mouths of the Oaro Stream and the Conway River and elsewhere raised beaches representing the last uplift of the land occur only a few feet above sea-level. Very fine fluvio-marine terraces, with tops approximately 40 ft., 50 ft., and 200 ft. above the sea, also distinguish the mouth of the Conway. Northward near Claverly homestead the 200 ft. terrace is clearly observable, whilst the almost flat tops of Amuri South and Amuri Bluffs also indicate marine erosion at approximately the same contour. West of Claverly homestead a well-marked terrace appears at approximately 400 ft. elevation, and again almost on the top of the hills overlooking the coast are outcrops of beach shingle and sand at a height roughly estimated at nearly 600 ft.* McKay gives the height of the highest terrace gravel as seen on Amuri Bluff Hill as 500 ft., and mentions that it is there fossiliferous (6, pp. 177–78; 11, p. 127; 16, p. 182). Hutton mentions the terraces and sea-cut platforms of this district in his earliest report (4, p. 55). Recently J. A. Thomson reports fossiliferous sandy beds in the valley of Oaro Stream at an elevation of 900 ft. (22, p. 8). Since, however, the contained fossils indicate a Pleistocene age, it is likely that the beds in question belong to an earlier period than the series of raised beaches here described, and, in fact, there is room for a suspicion that they form part of the Upper Tertiary beds now to be described.

Upper Tertiary Beds ("Great Marlborough Conglomerate").

On or near the road from Te Oaro to the Conway River numerous outcrops of a conglomerate post-dating the Grey Marl may be observed. This rock, together with some associated fine-grained beds, may without much hesitation be correlated with McKay's "Great Post-Miocene Conglomerate," called by Thomson and Cotton the "Great Marlborough Conglomerate," a non-committal name that will be adopted in this report.

The first outcrop to be noted is not far south of Te Oaro School, where on the east side of the road is steeply dipping conglomerate composed of medium gravel intermingled with large masses of various kinds of rock, including Grey Marl. This conglomerate rests on a fault-plane, below which is a hard calcareous mudstone, presumably the Grey Marl. It is noteworthy that the fault follows a bedding-plane of the latter rock, and hence there is an appearance of conformity between the Grey Marl and the conglomerate.

Southward from the saddle leading into Okarahia Stream conglomerate outcrops in the road-cuttings for a considerable distance. The rock consists of bands of medium greywacke conglomerate, interbedded with layers of bluish claystone, but here and there exhibits its characteristic feature, a liberal admixture of great angular boulders of greywacke, Amuri limestone, and Grey Marl many feet in diameter. Not far from the point where the road crosses Okarahia Stream the conglomerate is abruptly terminated against crushed greywacke by a strong reversed fault.

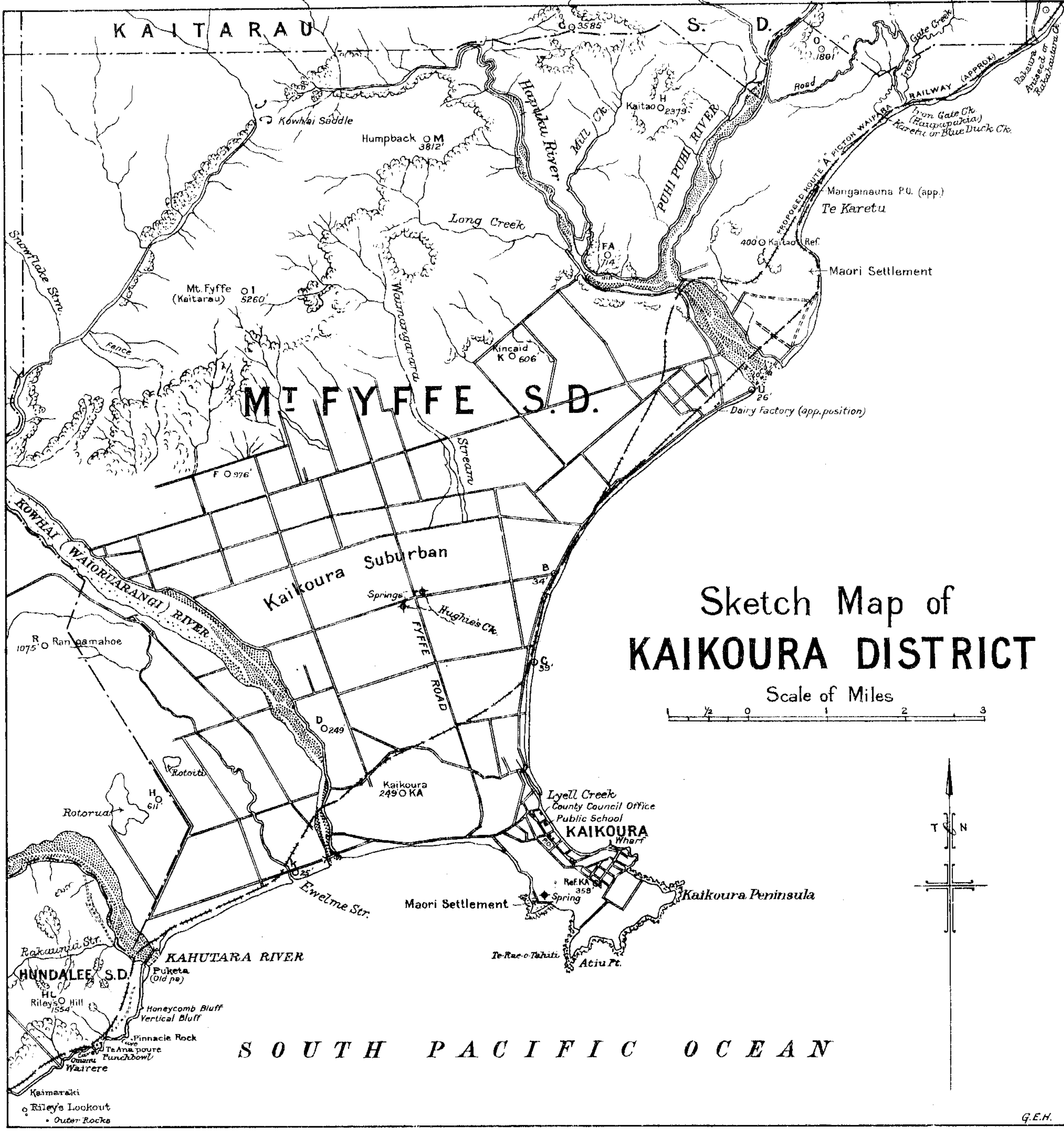
The next appearance of the Upper Tertiary rocks is near the saddle south of Hundalee Post-office (Norrie's), where the road-cuttings expose outcrops of conglomerate and claystone, more or less intermingled by faulting movements. The conglomerate, which contains a number of marine fossils, consists mainly of small pebbles of greywacke, with some Amuri limestone, flint, &c. South of the saddle and for some distance towards the Conway River there are good exposures of conglomerate interbedded with blue claystone, which was not observed to be fossiliferous or calcareous. In places the conglomerate is composed only of small or medium-sized pebbles in a matrix of finer material, whilst elsewhere it contains huge angular blocks of greywacke and bluish claystone (presumably Grey Marl). At one point on the roadside conglomerate appears to rest unconformably on bluish claystone (? Grey Marl).

Everywhere from Te Oaro to the Conway River the Great Marlborough Conglomerate is more or less fault-involved, and exhibits strong dips, all in a westerly direction so far as the writer's recollection serves.

Relation of Conglomerate to Grey Marl.—C. A. Cotton has not merely cast suspicion upon the supposed unconformable relation of the Great Marlborough Conglomerate to the Grey Marl, an unconformity which was never doubted by McKay, but has maintained that in the Clarence Valley the opposite relation holds good (25, pp. 350 *et seq.*). A consideration of the data afforded by the outcrops of the conglomerate between Te Oaro and the Conway River, together with those obtained in the Cape Campbell district, leaves no doubt in the writer's mind as to the existence of unconformity between the two rocks. A passing glimpse of the coastal outcrops near Kekerangu gives a similar impression. Thus the coastal region, which, however, was expressly excepted by Cotton from the scope of his paper, apparently lends no support to that author's views.

When one considers the inherent probability of a conglomerate containing numerous boulders derived from underlying strata being unconformable to those strata, when McKay's powerful testimony is given due weight, and when the similarity of all the occurrences is taken into account, Cotton's hypothesis of conformity in the Clarence Valley, with its various corollaries, fails to carry conviction. It may be suggested that the apparent continuity observed by Cotton

* All terrace heights mentioned in this report were estimated by means of the eye only.


Sketch Map of
KAIKOURA DISTRICT
Scale of Miles
KAITARAU S.D.
Mt. FYFFE S.D.
HUNDALEE S.D.
Kowhai Saddle
Humpback M 3812'
Mt. Fyffe (Kaitarau) I 5260'
Kaitao H 2379'
Hapuku River
Mill Ck.
PUHI PUHI RIVER
Long Creek
Waimangarara
Kincaid K 606
Snowflake Str.
Fence
KOWHAI (WAIORUARANGI) RIVER
Kaikoura Suburban
Springs
Hughes Ck.
FYFFE ROAD
Stream
Ranqamahoe
Rotoiti
Rotorua
Kaikoura 249 KA
Lyell Creek
County Council Office
Public School
KAIKOURA
Wharf
Maori Settlement
Spring
Kaikoura Peninsula
Te-Rae-o-Tahiti
Atiu Pt.
Ewelme Str.
KAHUTARA RIVER
Rakautara Str.
Puketa (Old pa)
Rileys Hill 1554
Honeycomb Bluff
Vertical Bluff
Pinnacle Rock
Cave
Punchbowl
Wairere
Kaimarati
Riley's Lookout
Outer Rocks
Dairy Factory (app. position)
Maori Settlement
Te Karetu
Mangamaunu P.O. (app.)
PROPOSED ROUTE A PICTON WAIPARA RAILWAY (APPROX)
Iron Gate Ck.
Gate Creek
Road
Kaikoura Ck.
SOUTH PACIFIC OCEAN
G.E.H.

1250-6.16-392.

is either due to faulting bringing blocks of unconformable beds into juxtaposition and parallel attitudes, or is a conformity between the conglomerate and beds much younger than the Grey Marl, but lithologically similar.

Unconformity above Amuri Limestone.

On the rock-shelf a short distance south of Amuri Bluff a contact between Amuri limestone and a thin upper limestone is very clearly shown, and is of exactly the same character as at Kaikoura Peninsula. The irregular upper surface of the Amuri limestone is penetrated by numerous small cavities and tubular passages (worm-borings) filled with calcareous glauconitic sandstone. On this surface rests 6 in. of conglomerate, composed of phosphatized pebbles of limestone,* set in a small amount of calcareous greensand matrix. This is followed by 2 ft. or 3 ft. of calcareous greensand, containing numerous pebbles of limestone, some 2 in. or more in diameter. Many of these weather to a black colour, and are no doubt phosphatic. Above the greensand is 10 ft. to 15 ft. of limestone, followed with apparent conformity by grey calcareous sandstone passing upward into a more argillaceous rock (Grey Marl). The phosphatic conglomerate may be seen for some distance on the rock-shelf, and also in the cliff to a point near the natural tunnel at the outermost portion of the Amuri Bluff. It is described by von Haast as a greensand conglomerate (2, p. 43), by Hector as a layer of brecciated fragments of calcareous greensands (3, p. xi), and in 1877 by McKay as a greensand conglomerate, which is, he says, a most peculiar bed, consisting of nodules of a calcareous greensand in a mātrix of greensand, and, although apparently incoherent, is often of extreme hardness" (6, p. 179). He also states that it contains fossil bones, including those of a penguin (8, pp. 584, 585), and an oyster (13, p. 77). Years later the last-named writer speaks of it as a "bed of phosphatic nodules in a matrix of rather loose greensands" (16, p. 164). In the meantime the presence of phosphatic nodules in a corresponding horizon at Weka Pass had been determined, but there is no record of any analysis of the Amuri Bluff conglomerate having been made. Be this as it may, McKay's statement, though probably merely a shrewd guess, is correct, as is shown by the following analysis of a sample selected near the most southern outcrop on the foreshore: Calcium carbonate ($CaCO_3$), 45·86 per cent.; phosphoric anhydride (P_2O_5), 19·91 per cent. The phosphoric anhydride is equivalent to 43·46 per cent. of tricalcic phosphate.

The next locality where the unconformable contact of Amuri limestone with the overlying rock may be observed is some distance north of Mikonui (Mikinui) Creek. Here there is a peculiar section, which may be described as follows:—

Grey Marl (calcareous sandstone), underlain by —

- 12 ft. to 15 ft. of calcareous rock, the lower part with many pebbles of limestone, reaching 1 in. to 2 in. in diameter.
- 5 in. to 14 in. calcareous phosphatic conglomerate, with a greensand matrix.
- Several feet of limestone, much eroded on its upper surface, with cavities extending to some depth, and filled with calcareous sandstone containing many small dark pebbles (probably phosphatized limestone).
- 2½ ft. to 3 ft. of calcareous sandstone with many pebbles (of limestone probably), which in a few feet both to the north and the south passes gradually into slightly glauconitic limestone.

The phosphatic conglomerate can be traced in the cliff-face for some distance to the north until it is cut off by a fault with downthrow to the northward. The Amuri limestone reappears a short distance farther north, but the conglomerate was not observed by the writer. Not very far to the west or north-west, however, a limestone cliff capped by Grey Marl may be seen on the east side of the main road up the Oaro Valley. Here, opposite a small clump of bush where a Public Works camp was situated in December, 1915, calcareous and presumably phosphatic conglomerate 6 in. thick is exposed for a length of 6 ft. a little above the road-level. At one end debris hides the outcrop, and at the other it is terminated by a fault. Calcareous strata overlie for 40 ft. or 50 ft., and above these comes the Grey Marl proper.

Economic Geology.

The remarks made on a previous page with respect to the phosphatic conglomerate at Kaikoura apply equally well to that in the Amuri Bluff district. Many years ago the limestone at Amuri Bluff was quarried as a building-stone and for the manufacture of quicklime (1, p. 39; 2, p. 38), but the enterprise has long been abandoned. Much of the limestone appears to be of good quality, and suitable for both the purposes mentioned. The lower horizons, however, contain numerous flinty concretions and are of little value, except that they are the source of large quantities of flint pebbles which have accumulated on the shore not far north of Amuri Bluff. Though the majority of these are flattened by erosion, and therefore narrowly ellipical in cross-section, like most shingle pebbles, yet a portion of them may be suitable for use in tube mills, and in days to come may find other uses.

WAIPARA, WEKA PASS, AND WAIKARI DISTRICTS.

Several days spent in the Waipara and adjoining districts were largely devoted to examining the contact between the Amuri limestone and Weka Pass stone. The observations made on the whole support Hutton's view that the contact is unconformable. On the other hand, the

* The assumption that the phosphate of lime replaces the carbonate of lime in limestone pebbles is made owing to the analogy with Weka Pass. It has not been strictly proved.

contact of the Weka Pass stone and the overlying Grey Marl* wherever seen appeared to be perfectly conformable. Evidence of an unconformity at the base of the Mount Brown beds was also noted, and some scanty all-too-incomplete data concerning the faults traversing the area examined were obtained. The general geology of the Waipara and Waikari districts is described in the last annual report of the Geological Survey (26, pp. 90–93), and in the publications there cited, so that no summary need be given on the present occasion.

Unconformities.

(1.) *Amuri Limestone and Weka Pass Stone Contact.*—Near Weka Pass and Waikari this contact is everywhere of the same character as that described in the last annual report of the Geological Survey (26, pp. 90–93)—that is, it is marked by an eroded surface of Amuri limestone, upon which rests a thin, calcareous glauconitic sandstone containing limestone pebbles which passes gradually into the Weka Pass stone. One or two observations may be added to those made last year. In various places small tubular passages in the Amuri limestone now filled with glauconitic sandstone are undoubtedly worm-borings, whilst between Waikari and the middle gorge of the Waipara River "fucoid" casts are abundant in the lower part of the glauconitic sandstone. Small externally black pebbles, which look like greywacke but are really phosphatized limestone, occur in the glauconitic sandstone to a height of 4 ft. above the Amuri-limestone surface. One or two small quartz pebbles occur near the contact in the railway-cutting, and in one locality a single flint pebble, 1½ in. by 1 in. by 1 in., was observed 1 ft. above the contact. The following part analyses of calcareous phosphatic pebbles collected from the horizon last December may here be quoted:—

	(1.) Per Cent.	(2.) Per Cent.
Insoluble in acids	4·34	7·30
Calcium carbonate ($CaCO_3$)	24·11	48·09
Phosphoric anhydride (P_2O_5)	22·56	13·65

The phosphoric anhydride in (1) is equivalent to 49·29 per cent. of tricalcic phosphate ($Ca_3P_2O_8$); that in (2) to 29·96 per cent.

No. 1 sample consisted of pebbles with dark exterior, and No. 2 of light-coloured pebbles. Both were collected on the west side of the road some distance south of Weka Pass Saddle and of the railway viaduct. They are similar in composition to the "phosphatic nodules" collected in the same horizon by McKay many years ago (14, p. 84), but differ from the calcareous pebbles collected by the present writer in March, 1915 (26, p. 92, analysis No. 4) near the railway viaduct.

As the contact is followed southward from Weka Creek valley towards the second gorge of the Waipara River it gradually changes in appearance. The pebbles of limestone marking the contact become fewer, and about a mile from the Waipara River disappear. Not only so, but the water-worn aspect of the upper surface of the Amuri limestone also gradually becomes indistinct, whilst the overlying glauconitic sandstone becomes less glauconitic and more calcareous, so that the contact is marked only by a slight change of lithological character, by the presence of numerous "fucoid" casts, and by small oval grey patches, apparently more sandy than the enclosing rock, some of which are surrounded by a ring of iron oxide. Thus at the second gorge of the Waipara River there is no visible evidence of physical unconformity, but since numerous similar contacts in other parts of the world are regarded by competent geologists as unconformable, and in some cases without dispute, it is still possible to accept the Amuri limestone and Weka Pass stone contact as representing a stratigraphical break.

The Weka Pass stone generally overhangs the Amuri limestone contact owing to its lowest layer being softer and more easily eroded than the rock above or below, and thus a shelf appears at the junction. In the middle Waipara Gorge a shelf, marked by shrubs, is formed at the expense of the uppermost layer of Amuri limestone, here softer than the overlying rock.

The only recognizable fossils seen by the writer near the junction, other than "fucoid" casts and the crustacean(?) mentioned below, were two specimens of *Epitonium* (probably *E. rugulosum lyratum* (Zitt.)) in very sandy Weka Pass stone 4 ft. or 5 ft. above the Amuri limestone. The locality is just to the south of the watershed between Weka Creek and the Waipara River (north-west of Mount Dean). A little farther south a loose block of Weka Pass stone was observed to contain what seemed to be the remains of some crustacean. Thomson and Cotton found somewhat numerous specimens of *Pecten huttoni* (Park) in the same horizon (22, p. 8), and Mr. Alex. McKay has personally informed the writer that in a locality south of the Waipara River whale bones are abundant close to the junction of Weka Pass stone and Amuri limestone. This is probably the bone horizon mentioned by him in an early report (5, p. 38).

(2.) *Contact of Grey Marl and Mount Brown Beds.*—In many places the contact of the Grey Marl with the overlying (Mount Brown) beds is obscured by soil and debris. A clear junction, however, is visible in a small gorge of Weka Creek, about half a mile west of the road through Weka Pass, and affords very satisfactory proof of the unconformity maintained by Hector and McKay (12, pp. xi–xii; 18, p. 102, &c.) as present between Grey Marl and Mount Brown beds. In this locality the upper surface of the Grey Marl (here a fine-grained calcareous argillaceous sandstone) is irregularly eroded, and succeeded by layers of calcareous shelly greywacke and current-bedded sandstone containing pebbly beds or lenses composed largely of Grey Marl fragments. At one spot the first few inches of the soft sandstone immediately above the Grey Marl

* McKay's correlation of the bluish-grey mudstone or fine-grained sandstone overlying the Weka Pass stone with the Grey Marl is here provisionally accepted. For a discussion of this point see Thomson in the Sixth Annual Report of the Geological Survey (22. p. 9).

contains numerous pieces of that rock, thus recalling the Amuri limestone and Weka Pass stone junction in its typical aspect. A chain or two away the contact is devoid of pebbles, and soft brownish sandstone lies on a slightly irregular surface of hard bluish fine-grained sandstone.

From Weka Creek to the second or middle gorge of the Waipara appearances are consistent with a varying thickness of the Grey Marl, a condition in favour of unconformity. A quarter of a mile or more below the point where the limestone belt crosses the Waipara River a slight synclinal roll in the Grey Marl does not pass into the overlying Mount Brown beds, but this occurrence is not necessarily of such a character as to indicate unconformity. A contact of Grey Marl and probable Mount Brown beds seen in the gorge from a distance of 150 yards appears at first sight to be conformable, but no weight can be attached to this observation—a hasty one—until it is confirmed by a close examination. On the contrary, McKay when speaking of this locality states, "A stratigraphical unconformity is here evident enough in the section displayed in the right bank of the river, and again a little further down on the left bank of the river" (18, p. 102).

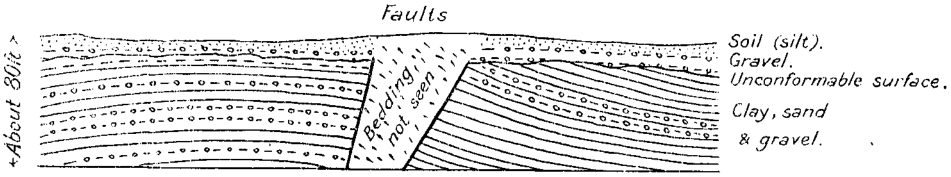
Hector very strongly supports the view that the Mount Donald—*i.e.*, Mount Brown—beds unconformably overlie the Grey Marl in the Weka Pass, and gives a section and plan in confirmation (12, pp. xi–xii).

Some miles south-east of Waipara a high cliff on the south side of Washcreek Road shows blue claystone or fine sandstone (Grey Marl), followed with apparent slight unconformity by a soft sandstone, evidently part of the Mount Brown beds. Here again further examination is necessary before the observation can be given credit.

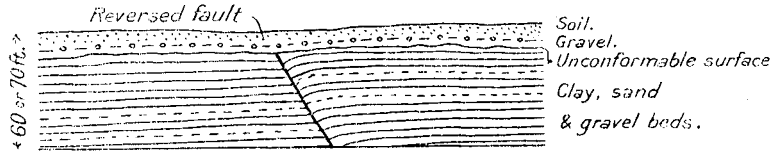
(3.) *Unconformities post-dating Mount Brown Beds.*—About two miles south-east of Waipara Township the cuttings of Washcreek Road show loose sand and shingle unconformably overlying fossiliferous sand conglomerate (? Motunau beds). On the south bank of the Waipara River, west of the road-bridge, a distinct unconformity may be seen in the Quaternary strata there exposed. (See Figs. 1 and 2 under the heading of "Faults.")

Faults.

Numerous faults, few of which have been indicated on the geological maps or sections compiled by various geologists, traverse the Waipara and Waikari districts. Hutton was the first to observe an important east-and-west fault with northerly downthrow that dislocates Cretaceous and Tertiary strata at the second or middle gorge of the Waipara River (4, p. 45 and



(1). Section on south bank of Waipara River, 1 mile above road bridge.



(2). Section on south bank of Waipara River, 1½ miles above road bridge.

section ix, opposite p. 56; see also 8, pp. 268, 269). The same geologist also mentions a fault in the Weka Pass (4, p. 45 and section x). One or two other small dislocations may be seen in the same locality (14, p. 86). Probably a strong east-and-west fault passes through Waikari Township just to the south of the railway-station.

More common than the east-and-west faults are those with strikes varying from nearly north and south to north-east and south-west. In all probability a great fault at the foot of Doctor's Range separates the Cretaceous rocks to the east from the Trias-Jura (or older) rocks to the west. West of Waikari this fault either bends to the west of north or is replaced by a series of dislocations striking in that direction. Between the second gorge of the Waipara and Waikari the limestone belt is obliquely intersected by several moderate faults, the most prominent of which is perhaps that seen where the Amuri limestone crosses Weka Creek. The limestone of the Mount Cass Range east of Waipara is broken in several places by faults of small or moderate throw. The later Tertiary strata (Mount Brown or Motunau beds) at the inland entrance to the lower Waipara Gorge dip at high angles, and are probably dislocated by a strong fault striking north-eastward and having downthrow to the north-west.

The Quaternary or, at least very late Tertiary, age of some of the faults is shown by the occurrence of two faults intersecting the late Pliocene or more probably Pleistocene gravels and clays exposed on the south bank of the Waipara River one mile and one mile and a half respectively west of the main road bridge. The one nearer the bridge appears to be a normal fault (really a narrow fault-zone) with considerable downthrow to the north-eastward. A small flat-topped hill, immediately to the south-west, almost certainly owes its origin to the conditions produced by this fault. It is worthy of note that a trigonometrical station placed on this hill has received the name of "Mound." The second dislocation is a small reversed fault with upthrow of 20 ft. or more to the west or south-west. Sketches (1) and (2) diagrammatically illustrate these faults.

Economic Geology.

The Weka Pass stone many years ago was quarried to some extent for building purposes (2, p. 13; 4, p. 43), but its use in this connection seems to have been discontinued. The Amuri limestone, though everywhere somewhat siliceous, is in places sufficiently pure to furnish lime of fair quality. The soft-limestone deposits of the Waikari and Weka Pass district are described in another report. Their value for agriculture has yet to be determined by exploration and experimental work. Although the phosphatic horizon marking the unconformity above the Amuri limestone at Kaikoura and Amuri Bluff is present in the Waikari and Weka Pass districts, no locality where phosphate is present in commercial quantity has yet been discovered.

Discussion of Unconformities.

If the very late Tertiary or Quaternary unconformities observed near Waipara be disregarded as of no great importance, there remain three or four supposedly unconformable horizons to be discussed—namely (1) between the Amuri limestone and the Weka Pass stone, (2) between the Weka Pass stone and the Grey Marl, (3) between the Grey Marl and the Mount Brown beds, and (4) below the Great Marlborough Conglomerate. All these unconformities have been strongly affirmed and just as strongly denied by geologists of repute, so that the student who has not had an opportunity of examining the typical sections at Kaikoura, Amuri Bluff, Weka Pass, and elsewhere for himself feels at a loss what to believe. From the data given here and in other papers by the writer it is not unreasonable to conclude that the stratigraphical break between the Amuri limestone and the overlying Weka Pass stone is widespread, whilst that between the latter rock and the Grey Marl, being seen only at Kaikoura Peninsula, is merely local. The next break, that above the Grey Marl, is probably tolerably widespread, especially if the unconformity below the Great Marlborough Conglomerate be considered to come into this horizon. More probably, perhaps, the last-named break is at a higher point in the geological succession. At present in no case, unfortunately, have we sufficient palæontological data for enabling the time value of the break to be estimated.

The fact that no marked discordance in strike or dip can be found in the succession of beds from Cretaceous to upper Tertiary has led Marshall and others to advance the view that perfect physical conformity exists from top to bottom of a Cretaceo-Tertiary sequence in all parts of New Zealand (19, 20, 21, &c.). Though of a bold simplicity, this conception has not been fruitful in any respect save the promotion of discussion and a temporary thickening of the cloud of confusion involving an admittedly difficult problem. Under these circumstances the writer hesitates in making the new, or partly new, suggestion—and it is not intended to be anything more than a suggestion—that since the deposition of the Amuri limestone there have been many movements producing local unconformity in different areas, but none (with perhaps one exception) that affected the whole of New Zealand simultaneously, at least in the same way and to a like degree. Hence there may be no universal post-Amuri unconformity, but a series of local stratigraphical breaks, comparable to a number of faults disposed *en echelon*, in places overlapping, but as a rule not uniting so as to form a continuous fracture. In the absence of sufficient palæontological data it is not possible to decide whether the break above the Amuri limestone is of major importance or represents only a minor land-movement. The physical criteria as they stand seem in favour of the latter view, whilst the scanty palæontological evidence tends the other way. To some extent the few fossils reported as collected from the Amuri limestone indicate a Tertiary age for that much-disputed rock, but there can be no doubt that some of these came from the conglomerate, greensand, and limestone overlying the Amuri limestone proper, and therefore above an unconformity. Though McKay, the chief collector, usually distinguished the upper limestone as the "Weka Pass stone," it is by no means certain that he always did so. One fact not hitherto mentioned is significant, or rather may be so. Kaikoura, Amuri Bluff, and Weka Pass are points on what is practically a straight line, and that straight line is parallel to the trend not to the South Island, but of the Southern Alps and their continuation, the Spenser Range. Can we suppose that whilst the Southern Alps were being uplifted, probably for the first time, a sympathetic but much less pronounced movement raised the Amuri limestone and any overlying strata to or above sea-level, and that subsequently, depression having taken place, the Weka Pass stone and its equivalents were deposited on the eroded but almost imperceptibly tilted surface of the older rock? Such a supposition, though ill founded on facts, is in accordance with those that are known. When data are scanty, however, hypotheses are easy to construct, and what is needed is rather the accumulation of facts through the extension of detailed surveys and palæontological research, so as to obtain a solid foundation for theoretical conclusions.

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8. SCHEELITE AND WOLFRAM (TUNGSTEN ORES) IN NEW ZEALAND.

(By P. G. Morgan.)

Scheelite occurs at Saddle Hill, near Dunedin; Stony Creek and other localities near Waipori; Carrick Range; Bendigo (Cromwell District); in the gravels of many streams in the Lake Wakatipu district, and in lodes near Glenorchy; in the Buckleburn Valley, at Mount McIntosh, &c.; at Mount Highlay, near Hyde; in the Macraes district; at Stoneburn, and various other localities in Otago; in the Jubilee Mine lode, Top Valley (Marlborough); in the Wakamarina district (Dominion Mine, &c.); and in the gravels of the Buller River at Newton Flat, Inangahua Junction, &c. It is also reported from the Mount Radiant district.

All the known New Zealand occurrences of scheelite *in situ* are in connection with more or less auriferous quartz lodes in mica-schist country. In other parts of the world tungsten minerals are generally found in granite. The mineral is found either as rich bunches or thinly disseminated through the quartz. In the former case it may be obtained by hand-picking the broken ores, whilst in the latter case fine crushing and treatment by some form of concentrating machinery is necessary.

Wolfram occurs in tin-bearing gravels, Stewart Island, and in a quartz lode, Mount Mantell (Murchison district). It is also reported from the Mount Arthur district, from the gravels of the Westport district, and from Mount Rangitoto (North Westland). In several of these localities there is a possibility of prospecting revealing workable deposits.

The principal scheelite-producing district in New Zealand for a number of years was Macraes, but at the present time comparatively little scheelite-mining is being done in that locality. From observations made during visits in 1909 and 1914, I think that an increase in the price of scheelite will lead to renewed activity in the Macraes and the adjoining Mount Highlay districts, followed by increased production. For several years there has been a considerable production in the Glenorchy district. From the Inspector of Mines' report made in 1913 it would appear that there is a large area of scheelite-bearing country, and that the industry is capable of great expansion (Mines Report, 1913, p. 35). There are several small claims on high country (4,000 ft. or 5,000 ft.) which can be worked only during summer.

In the adjoining Mid-Wakatipu district Professor Park states that there is reason to believe that quartz lodes carrying scheelite will be found between Moke Lake and Benmore, between Bob's Cave and Mount Crichton, and on the ranges round Lake Luna. (N.Z.G.S. Bull., No. 7, 1909, p. 94.)

The Alta lode, east of Bendigo (Cromwell district), which was worked for gold over forty years ago, carries a considerable amount of scheelite. The descriptions of it given by G. H. F. Ulrich, A. M. Finlayson, and J. Park all agree in regarding the lode as worth reworking.

A 2 ft. gold and scheelite lode at Saddle Hill, worked for a short time about 1889–90, and at that time visited by me, is, I believe, worth reopening. The scheelite-saving appliances used were crude, and the price of the mineral was low, so that much better results might be expected to-day than were possible a quarter of a century ago.

During 1914, 204 tons of scheelite concentrate and ore, valued at £21,498, was exported from New Zealand. For 1915 the corresponding figures are 194 tons and £27,784. The decrease of 10 tons in the production, though small, is somewhat surprising, in view of the greatly increased price of tungsten ores since February, 1915, but is partly to be explained by the uncertainty of the market during the preceding six months. This factor probably affected the 1915 production more than that of the preceding year.

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9. NOTES ON THE LIMESTONES OF THE MANAWATU GORGE AND OF MAURICEVILLE.

(By J. Henderson, Mining Geologist.)

The writer, in company with Mr. B. C. Aston, Agricultural Chemist, paid a hurried visit to the above-named localities on the 10th September, 1915.

The sequence of the Tertiary beds exposed between the Manawatu Gorge and Woodville has been described by McKay* and Park,† the latter of whom also illustrates his report by a section. As noted by these writers, several limestone layers occur intercalated with conglomerate and sandstone beds always more or less calcareous. The conglomerate bands consist of well-rounded cobbles set in a matrix chiefly made up of very well smoothed grit-sized particles, while the limestone beds are mainly formed of shell fragments and contain throughout numerous grit particles and occasional layers of rounded stones. The whole succession is clearly of littoral origin, and the beds were laid down as the beach deposits of a Tertiary sea, the land area of the region considered being at that time represented by what is now the Tararua–Ruahine Range. In such deposits the alteration in nature and texture of the different beds is very rapid. Thus the limestone band which above the Gorge Railway-station is perhaps 40 ft. in thickness grades to the dip into a calcareous sandstone containing numerous scattered stones. The examination made was insufficient to determine its horizontal variation, but from considerations of the origin of the deposit it is unlikely that its variation will be as rapid along the strike as down the dip. In this locality the strike varies between 25° and 40° east of north, while the dip is eastward at about 40°, with a flattening of the beds on the hill-tops. Where the Railway Department is at present obtaining ballasting-material the limestone layers are decidedly thicker and the rock itself contains as a whole fewer grit particles. The strike is here about 70° east of north, with a southerly dip of about 60°. This locality is much better suited for the opening of a quarry for the supply of ground limestone than that at the Gorge. Not only is the rock here more friable, but it contains less grit and fewer pebbles, while the amount available is many times greater.

At Mauriceville the limestone deposit is also indubitably of littoral origin. The rock is made up of shell fragments and contains a few particles of greywacke, while towards the top a layer of calcareous conglomerate perhaps 6 ft. in thickness is interbedded. The whole is overlain by blue fossiliferous sandstone, but contact with the underlying strata, which also consist of sandstone, was not observed. Where worked the limestone strikes about 170° and dips eastward at a very steep angle, its thickness here being about 300 ft. Southward the limestone is decidedly thinner, being replaced by conglomerate, of which a section is well exposed in a cutting on the road to Mauriceville West, 20 chains from the railway-station. A similar condition is reported to obtain to the northward, but the writer did not explore the district in this direction.

The deposit contains a very large tonnage of high-grade limestone, and is admirably situated for cheap exploitation. With a more up-to-date method of quarrying and modern drying machinery ground limestone could be produced at a cost materially lower than at present.

The following fossils, most of which were given to the writer by Mr. G. Dryden, manager of the Mauriceville Lime Company's works, have been determined by Mr. H. Suter:—

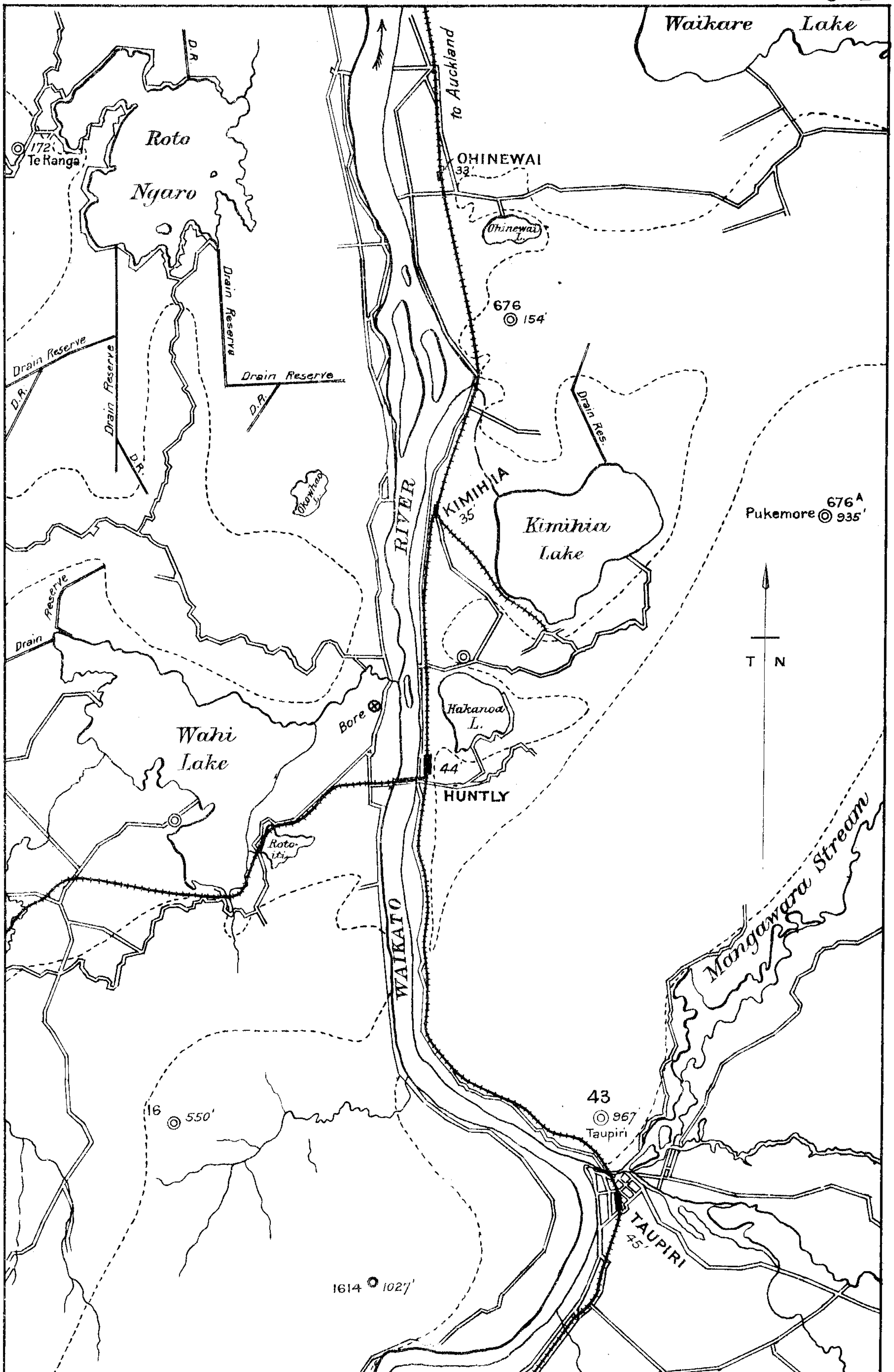
Manawatu Gorge: *Ostrea tatei*, Suter (= *O. hippopus*, Tate, non Lamarck).

Mauriceville: *Calliostoma pellucidum* (Val.); *Calliostoma selectum* (Chemn.); *Siphonalia mandarina* (Duclos) (?); *Mytilus canaliculus* (Martyn); *Panopea zelandica*, Q. and G.; *Astraea sulcata* (Martyn); *Lithophaga truncata* (Gray).

All the species mentioned are found Recent, and the last two have not hitherto been recorded fossil.

* McKay: "Report on the Country between Masterton and Napier." Rep. of Geol. Expl. during 1876–7, No. 10, 1877, pp. 75–6.

† Park, J.: "On the Geology of the Western Part of Wellington Provincial District and Part of Taranaki." Rep. of Geol. Expl. during 1886–87, No. 18, 1877, p. 34.



Sketch Map of Huntly District

SCALE

CHAINS 80 40 0 1 2 3 MILES

Recent. Pleistocene and Tertiary. Early Mesozoic.

10. NOTES ON THE HUNTLY DISTRICT.

(By J. Henderson, Mining Geologist.)

The district in the neighbourhood of Huntly has been examined by several geologists, who have recorded their observations in the following publications :—

1867. Hochstetter, F. von : "New Zealand," pp. 80–81, 302–306.

1867. Hutton, F. W. : "Geological Report on the Lower Waikato District." (Rep. Geol. Explor., No. 2.)

1877. Cox, S. H. : "Report on Raglan and Waikato Districts," Rep. Geol. Explor. during 1874–76, No. 9, pp. 9–16.

1877. Cox, S. H. : "Report on Waikato District," Rep. Geol. Explor. during 1876–77, No. 10, pp. 11–26.

1877. Denniston, R. B. : "Summary Report of Coal Explorations, Auckland District," Rep. Geol. Explor. during 1876–77, No. 10, pp. 114–128.

1886. Park, J. : "Report on the Huntly-Raglan District," Rep. Geol. Explor. during 1885, No. 17, pp. 141–147.

The above writers are in substantial agreement as to the rock sequence, which is as follows :—

(1.) Recent gravel and sand.
(2.) Pleistocene gravel, sand, and clay.
(3.) Tertiary claystone, limestone, sandstone, and at the base again claystone with coal-seams.
(4.) Early Mesozoic argillite and greywacke.

The Mesozoic series forms the Hakarimata Hills, and on a gently undulating surface of these rocks the Tertiary strata rest. Only the lowest or coal-bearing horizon occurs in the area examined, and the rocks composing it consist of massive, occasionally arenaceous, claystone locally known as "fireclay." The layers both above and below the coal are similar, and when weathered closely resemble the clay and silt that form the Pleistocene beds. These latter were evidently deposited in an ancient valley-system eroded during a post-Tertiary uplift. The bulk of these deposits are of fluviatile origin, but near their base a layer of clay containing shells shows that the sea invaded the old valley as far as Huntly during the Pleistocene depression. Elevation during Recent times rejuvenated the streams, and the Waikato is now re-excavating the ancient valley. The Recent history of the area, however, is by no means as simple as the above statements imply. Thus at a very late period either a slight depression of the land or, more probably, a great increase in the load of the Waikato led to the river aggrading its bed and forming an extensive flood-plain. The remarkable series of shallow lateral lakes formed by the damming of its tributary valleys by the overloaded stream was produced at the same time.

The Taupiri Coal Company have shafts and numerous bores penetrating the post-Tertiary clays and sands to the coal-measures beneath. One borehole sunk from the flats, which are approximately 44 ft. above sea-level, reached a depth of 146 ft. before striking the Tertiary beds. It was in one of these bores that the clay with shells was struck, at a depth of 111 ft. from the surface and 34 ft. from the coal-measures.

On exposure to the air the claystone in which the coal-seams are contained developes cracks in all directions. When the rock outcrops and is strongly weathered these cracks are filled with a waxy translucent substance of a yellowish or reddish colour. At Huntly, in a quarry worked for clay, the weathered rock exhibits all stages of alteration, the minute veins of halloysite—for such the mineral proved to be—expanding to such a size and becoming so numerous that certain layers in the face resemble weathered breccia. The mass of the clay is then formed of secondary material, in which angular leached fragments of the original rock are set, often several inches apart. Samples were taken and analysed, with the following results :—

	(1.) Average Sample.	(2.) Veins in Clay.
Silica (SiO_2)	49·99	39·65
Alumina (Al_2O_3)	27·95	34·29
Iron oxide (Fe_2O_3)	1·48	1·58
Lime (CaO)	0·03	0·07
Magnesia (MgO)	0·16	0·14
Water at 100° C.	9·83	10·42
Combined water and organic matter	10·24	13·67
Alkalies	0·32	0·18
	100·00	100·00

Dr. Maclaurin reports that the samples are clays of very good plasticity, and that their colour when burnt is light brown.

Approximate Cost of Paper.—Preparation, not given; printing (1,350 copies including maps), £25.

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