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(P. G. MORGAN, Director.)

BULLETIN No. 14 (NEW SERIES).

THE GEOLOGY

OF THE

NEW PLYMOUTH SUBDIVISION,

TARANAKI DIVISION.

BY

EDWARD DE COURCY CLARKE.

ISSUED UNDER THE AUTHORITY OF THE HON. JAMES COLVIN, MINISTER OF MINES.

WELLINGTON.

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LETTER OF TRANSMITTAL.

Geological Survey Office,

Wellington, 6th May, 1912.

Sir,—

I have the honour to submit herewith Bulletin No. 14 (new series) of the Geological Survey Branch of the Mines Department. This Bulletin, which deals with the general and economic geology of the New Plymouth Oilfield, is the work of Mr. E. de C. Clarke, M.A., now of Auckland University College.

The field-work in connection with the preparation of this report was done by Mr. Clarke, under the direction of Dr. J. M. Bell.

The Bulletin contains fifty-eight pages of letterpress, together with two general maps, a geological map, and a large sheet giving a tabulated comparison of boreholes.

I have the honour to be,

Sir,

Your obedient servant,

P. G. MORGAN,

Director, New Zealand Geological Survey.

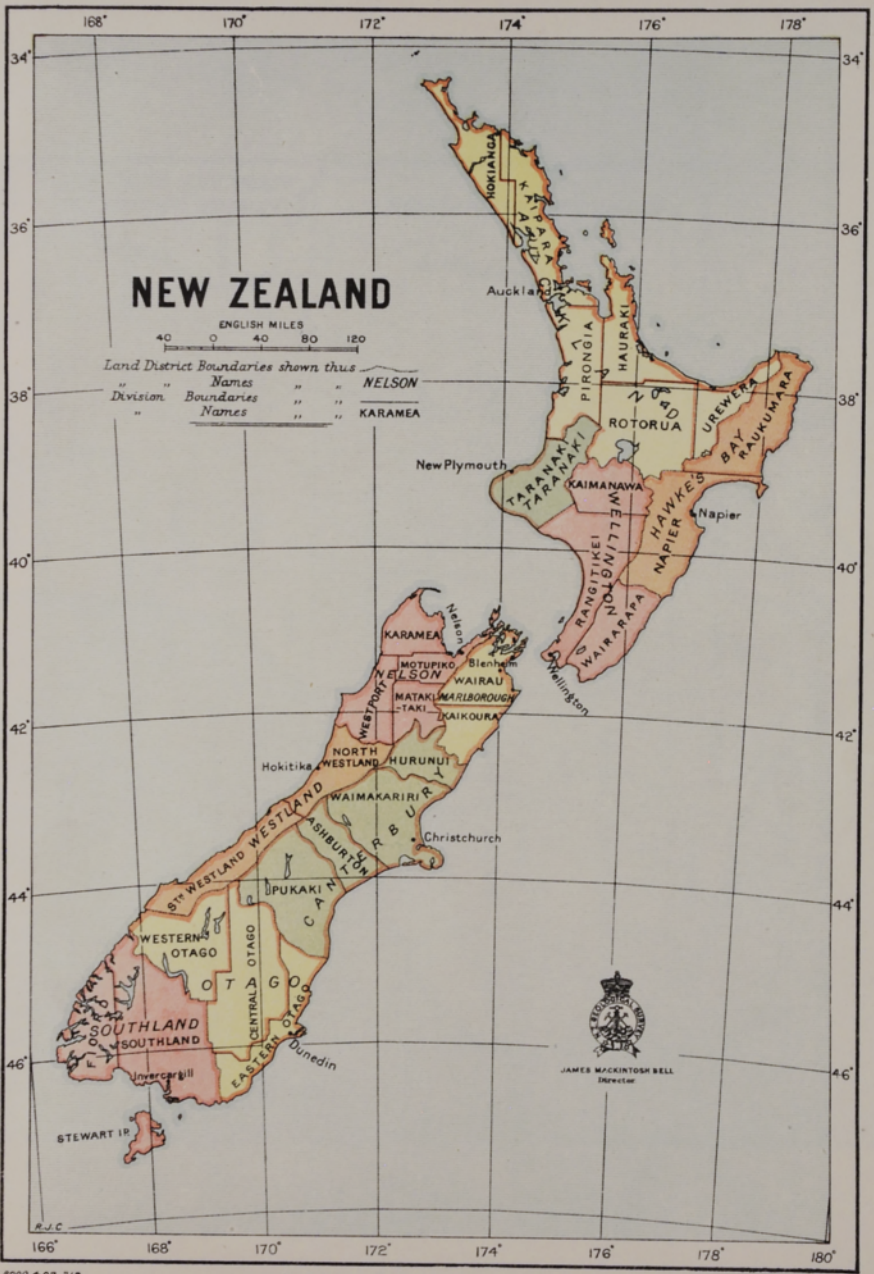
Hon. James Colvin,

Minister of Mines, Wellington.

CONTENTS.

CHAPTER III.—ECONOMIC GEOLOGY—*continued*.

MAPS.



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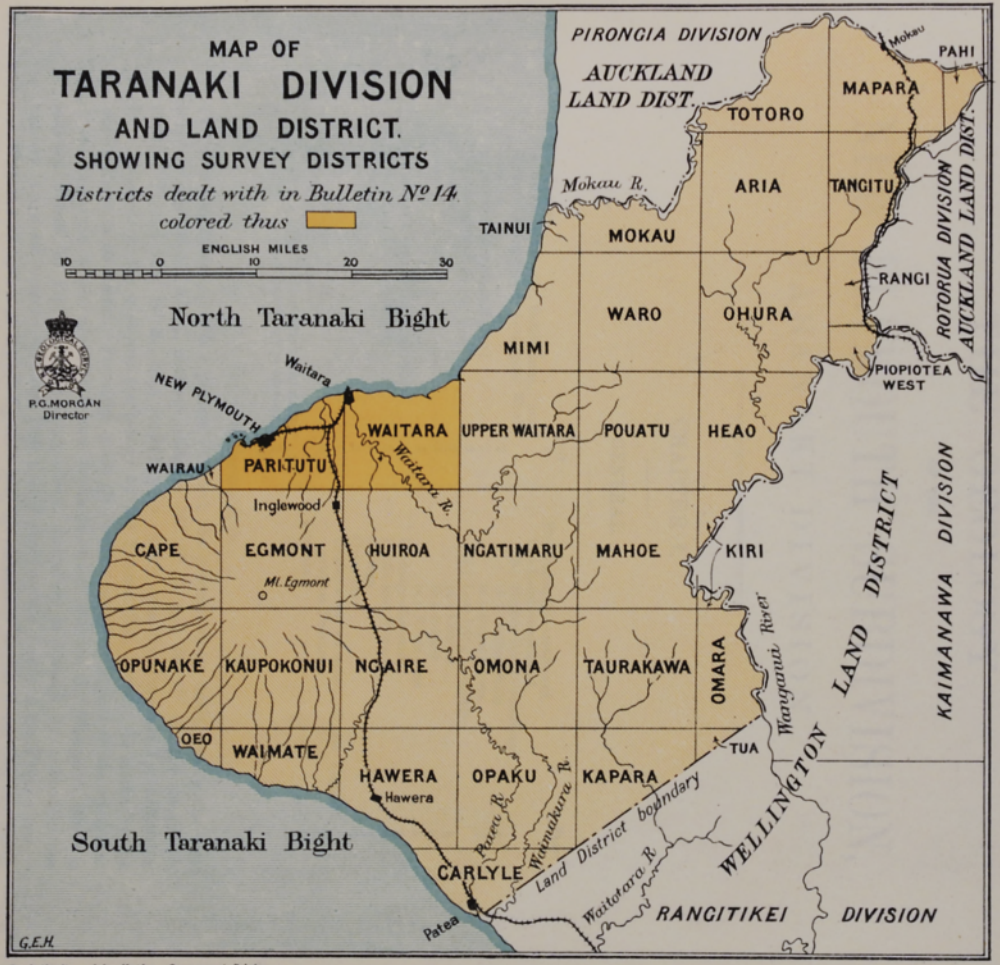

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BULLETIN No. 14 (NEW SERIES).

THE GEOLOGY

OF THE

NEW PLYMOUTH SUBDIVISION,

TARANAKI DIVISION.

CHAPTER I.

GENERAL.

INTRODUCTION.

THE Taranaki Division, with a portion of which the present report deals, lies on the west coast of the North Island between latitudes 38° 24′ S. and 39° 47′ S., and longitudes 173° 47′ E. and 175° 29′ E., thus coinciding in extent with the Taranaki Land District. It is bounded on the west and south-west by the Tasman Sea, and on the north by the Mokau River to its source. From this point the eastern boundary crosses to the watershed of the Ongaruhe River, which it follows to Taumarunui, whence the Wanganui River is followed almost to Pipiriki. The south-eastern boundary is formed by a straight line running in a south-westerly direction from near Pipiriki to the mouth of the Patea River.

With the exception of Mount Egmont and the subsidiary ranges in its neighbourhood, the Taranaki Division presents comparatively few features of interest from a scenic or geologic standpoint. The division, wherever settled, is almost entirely an agricultural and pastoral district, and at the present day is chiefly noted for its large output of butter. With the exception of mining for coal on the Mokau River, and of a moderate

amount of excavation for brickmaking and road-macadamizing, attempts to develop the mineral resources of the division have been confined to boring for petroleum, mainly in the immediate neighbourhood of New Plymouth; prospecting for gold and other metals in the Kaitaki or Patua Range; and to various attempts to smelt on commercially payable lines the ironsand which is found along the sea-beaches.

The New Plymouth Subdivision, and Economic Reasons for Geological Work therein.

The New Plymouth Subdivision, comprising the survey districts of Paritutu and Waitara, covers an area of approximately 218·2 square miles. It is bounded on the north by the shore of the North Taranaki Bight from the mouth of the Waiwere Stream, about three miles south-west of the New Plymouth Breakwater, to a point a mile and a quarter north of the mouth of the Mimi River, and thence by a straight line running due east for about half a mile. Of the remaining boundaries, the eastern and western are lines running south from the ends of the northern boundary as defined above, and the southern is a straight line running east and west through Huirangi Trigonometrical Station, which is about 10¼ miles due south of the mouth of the Waitara River.

Near New Plymouth a large amount of money has been spent during the last forty years in attempts to obtain, by boring, a payable supply of mineral oil, the existence of which in small quantities has been recognized since the earliest days of European settlement. Although there is no desire on the part of the writer to detract from the enterprise and public spirit which have often been marked characteristics of the various Taranaki petroleum ventures, it has to be admitted that transport facilities, ownership of properties, and other fortuitous circumstances have usually been the determining factors in the choice of bore-sites, and that little or no attempt has been made to unravel the geological structure of the country and to arrive at general conclusions as to the probable distribution of the petroleum.

The investigations detailed in this report were undertaken with the object of supplying such geological knowledge as would enable further oil-prospecting to be carried on in an intelligent and systematic fashion. With this purpose in view investigation was not strictly confined to the New Plymouth Subdivision, but was extended beyond it, as far as time would allow, whenever it seemed that by so doing further knowledge of the area under review would be gained.

Conduct and Character of Work.

The field-work detailed in this report was carried out in the two periods, November, 1909, to February, 1910, and November, 1910, to January, 1911. During the greater part of this time the writer had the assistance of Mr. R. W. Davies, of New Plymouth, whose intimate knowledge of the country was of very great value. All the information available at the Lands and Survey Office, New Plymouth, was plotted by the draughtsmen of the Geological Survey upon large sheets on a scale of 20 chains to the inch. Owing to the great amount of detailed work available from the Lands and Survey Office, it was found unnecessary to carry out any supplementary surveys—outcrops and other features being fixed with sufficient accuracy from the available data.

All ridges, streams, roads, and other features which seemed likely to afford information as to geological structure were examined, more especially in the eastern portion of the subdivision. In the western part of the area under review such close scrutiny was found to be unnecessary, nor was it possible in the more hurried reconnaissances made outside the subdivision.

ACKNOWLEDGMENTS.

The writer received much kindly assistance on all sides in Taranaki. The directors and employees of the Taranaki Petroleum Company and the New Zealand Standard Oil Company were ever ready to give all information in their power. To Mrs. G. C. Fair, and Messrs. D. Berry, F. P. Corkill, Foote, Murdoch Fraser, T. Furlong, T. H. Harle, R. C. Hughes, T. Nicholls, O. Samuel, Saxton, S. Percy Smith, T. P. Smith, Edward Trythall, and A. E. Watkins the writer wishes to tender his thanks for much assistance in a variety of ways. Mr. Frank Simpson (Chief Surveyor), Mr. W. H. Skinner (Chief Draughtsman), and other officers of the Lands and Survey Office in New Plymouth, promptly and courteously responded to all requests for topographical and other information. Unless otherwise stated, the analyses contained in this report were made by the Dominion Analyst, Dr. J. S. Maclaurin, and his staff.

INDUSTRIES.

The staple industry of the New Plymouth Subdivision is dairying. Almost all the available land of the subdivision has been cleared of the dense bush which at one time covered it, and has been subdivided into small farms. The amount of butter exported from Taranaki Province during 1907 was estimated at 5,693 tons, and that of cheese at 6,630 tons.

Large freezing-works, which during 1908 produced 6,220 tons of frozen meat, are in active operation at Waitara.

CLIMATE.

The climate of the area under consideration is warm, moist, and equable. As would be expected from its geographical position, the prevalent westerly winds usually bring rain, whereas the southerly and easterly winds are dry. The average monthly rainfall at New Plymouth, compiled from records extending over thirteen years, is as follows :—

——	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Average monthly rainfall in inches.	4·076	4·322	5·056	4·890	7·917	6·406	5·673	4·902	5·326	6·063	4·812	4·394

It should be noted that the rainfall in the southern part of the subdivision, towards Inglewood, is constantly higher than that near New Plymouth. Extremes of heat and cold are practically unknown. The following table shows the average monthly temperatures at New Plymouth, compiled from records extended over a period of twenty-five years :—

——	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Average monthly temperature in degrees Fahr.	64·43	64·53	62·45	59·18	55·57	52·19	51·13	51·10	53·96	56·75	59·36	62·99

SCENERY.

Within the subdivision itself the scenery is of the mild and pastoral order, enhanced by views of the open ocean. The magnificent volcanic cone of Egmont (8,260 ft.) to the south-west imparts, however, a certain distinctiveness to Taranaki scenery, and

saves it from any accusation of dullness or monotony. The coastal scenery is of a low, even character, varied just beyond the northern boundary by the imposing heights of the White Cliffs, and near New Plymouth by the rocky prominence which forms Paritutu, and the small skerries of a similar description known as the Sugar-loaves.

Towns, and Means of Communication.

The subdivision contains two towns of some size—New Plymouth and Waitara. The former is well situated on rising ground bordering the Tasman Sea, and forms the terminus of the railway to Wellington. New Plymouth owes its predominance over Waitara to prior settlement, and to the possession of a breakwater, which converts the open roadstead into a harbour, accessible in almost any weather to steamers not exceeding 400 ft. in length and 21 ft. in draught. The harbour improvements at present in active progress are expected, in two years' time, to allow of the berthing of vessels drawing as much as 28 ft.

The town of Waitara, though less advantageously situated from a scenic point of view, possesses a natural advantage in having the mouth of the Waitara River as the nucleus of a harbour. The town is also more central for receiving the greater part of the inland trade. Owing to the bar at the mouth of the river, the port of Waitara is open only to the smaller coastal steamers, which maintain a considerable trade with neighbouring ports. The large steamers, which load produce for export trade, have at present to be tendered both at Waitara and New Plymouth.

On land there is direct railway communication between New Plymouth, Waitara, and Wellington.

Numerous roads traverse the country in every direction, and these are, with very few exceptions, in an excellent state of repair. Post-offices and telegraph or telephone stations are widely distributed.

Population and Early History.

The population of the New Plymouth Subdivision, as judged from the census returns of 1911, is approximately 12,717, of which 5,240 persons are residents of New Plymouth (or 7,499 including the suburban area), and 1,452 of Waitara Borough.*

Taranaki was first settled by Europeans about the year 1840, when ships chartered by the New Zealand Land Company brought a number of emigrants, who were chiefly from Devonshire. No account of the vicissitudes of this settlement can here be given. The well-known Taranaki wars, which are fully recorded in various publications, have left many interesting landmarks in different parts of the subdivision.

Physiography.

Introduction.

At first glance the physiography of the district under review appears simple. Further examination seems, however, to disclose some anomalies which cannot be easily accounted for. The area may be described as a portion of an extensive plain of comparatively recent and intermittent elevation above sea-level. The sculpturing of this plain, now considerably advanced, varies markedly with the character of the underlying strata. The drainage-system of the whole area has been notably affected by the building-up of the volcanic cone of Egmont.

* Advance estimates of population were kindly supplied by the Government Statistician's Office.

THE LAND.

(1.) *General Relief.*

The land-surface of the New Plymouth Subdivision may be described in general as a deeply trenched plain showing no marked elevations, but exhibiting a distinct belt of higher country, which separates a zone of low country on the sea side from another area of low elevation on the inland (southern) side.

(2.) *Higher Land.*

(*a.*) *The Tapuae-Manganui Ridge and Terraces thereon.*—This ridge of higher land has a coastal width of about five miles and a half, extending from the town of New Plymouth to the mouth of the Tapuae Creek. From the sea-coast it may be traced in an easterly direction as far as the junction of the Manganui and Waitara rivers. From the eastern margin of the Manganui Valley the seaward edge of the ridge runs in an east-north-east direction, reaching the sea-coast at Pukearuhe, about two miles and a half north-east of the boundary of the subdivision. West of the interruption by the Manganui River the ridge is composed, so far as is known, almost entirely of volcanic débris of the Pouakai Series,* of Upper Miocene or later age. There is reason to suppose that, at some points at least, Miocene sedimentaries of the Onairo Series lie at no great depth below the surface. The inland margin of this portion of the ridge lies in most places near the southern boundary of the subdivision. East of the Manganui Valley the ridge abuts against higher land (rising to an average height of nearly 1,000 ft.) formed of the Miocene sedimentaries of the Onairo Series. East of the Manganui, therefore, the ridge really loses its ridge-like character altogether, and forms what may be generally defined as a terrace fronting the older rocks. The seaward margin of the ridge is difficult of exact definition, rising as it does from the lower coastal land in a series of terraces, of which four can generally be recognized. These terraces have been much dissected by the numerous streams.

(*b.*) *Conical Hills.*—In the neighbourhood of Lepperton, bordering on the seaward margin of the Tapuae-Manganui Ridge, and again just outside the south-east corner of the Partitutu Survey District, near Inglewood, occur assemblages of small conical hills, which it seems most reasonable to regard as the denuded remains of one or more volcanic cones. The Lepperton hills are scattered over an area of about nine square miles, and those near Inglewood over an area exceeding seven square miles. Further details regarding these hills will be found in Chapter II.

(*c.*) *Sugar-loaves.*—On the coast-line about three miles from New Plymouth the uniform character of the topography is strikingly interrupted by the occurrence of a group of exceedingly steep-sided pyramidal rocks. Of these, Paritutu and Mikotahi are on the mainland. Paritutu, the loftiest of the group, which rises precipitously from the sea-margin to a height of 505 ft., is bordered on the landward side by sand-dunes covered with vegetation. The rest of the rocks are islands of heights varying from a few feet to 268 ft., in the case of Moturoa, which, excepting Paritutu, is the most conspicuous of the Sugar-loaves. Outlying reefs doubtless mark the sites of similar prominences worn away by the action of the sea. With the exception of Mikotahi, the Sugar-loaves are composed of solid lava.

(3.) *Low-lying Country.*

(*a.*) *Coastal.*—The low-lying coastal belt has a maximum width of about six miles in a direction due south of Waitara, gradually narrowing to the east and west so that at the White Cliffs and near New Plymouth it is absent altogether. As may be seen from the

* For an outline of the geology of the subdivision, with descriptions of the series mentioned in this section, see Chapter II.

general map, this low-lying land is continued beyond the White Cliffs at least to Awakino, in the form of a terrace never much more than a mile wide fronting the higher country of Miocene rocks. There is little doubt that the low-lying coastal plain formerly extended far to the north and west of the present coast-line of the subdivision. Through this plain flowed the lower portions (now engulfed by the sea) of the Mokau, Mohakatino, and other rivers. Marine denudation has now advanced so far that but a narrow strip of the plain is left along the coast-line north of the White Cliffs.

The greater part of the coastal plain is similar in surface-conformation to the Tapuae–Manganui Ridge. It has a fairly uniform maximum elevation of about 200 ft., and is trenched and terraced by the numerous streams, which flow in a general northerly direction.

Immediately bordering on the sea the coastal lowland shows some development of sand-dunes. These are specially marked between the mouths of the Waitara and Henui rivers, where they attain a maximum width of nearly one mile near the mouth of the Mangaoraka River. Between the Breakwater at New Plymouth, where the sand-belt lies behind the upstanding Sugar-loaf of Paritutu, and the western boundary of the subdivision, the strip of sand does not usually exceed a few chains in width. The greatest height reached by the sand-dunes is about 100 ft.*

(*b*.) *Inland.*—The low-lying inland country south of the Tapuae–Manganui Ridge lies in great part beyond the southern boundary of the New Plymouth Subdivision. It will therefore be sufficient to note here that it is generally an open plain, through which flow in shallow beds the numerous streams that drain the slopes of Mount Egmont.

(*c*.) *River-flats.*—Flood-plains border the courses of all the streams in the subdivision almost to their headwaters, but none are of any great lateral extent. The most considerable flood-plain is that of the Waitara River, between Huirangi and the sea.

DRAINAGE-CHANNELS.

With the notable exception of the Waitara River, the streams and rivers of the New Plymouth Subdivision flow in a general northerly direction. Nearly all the streams pursue independent courses to the sea, the marked absence of tributaries being due to the comparative youth of the topography. In those parts of the coast where cliffs exist the smallest streams often enter the sea by means of waterfalls, but all except these flow through narrow flood-plains and enter the sea at grade. There is a marked distinction between the streams draining the western and north-central portion of the subdivision and those which occur in the south-eastern corner. The former follow an almost straight course through the volcanic débris of the Pouakai Series, varied by a small amount of meandering. In the south-eastern corner of the subdivision the water-courses follow more circuitous routes, and have cut out for themselves steep-sided gorges in the soft Miocene claystones and sandstones of the Onairo Series. In both classes of streams few, if any, waterfalls are to be found even near their headwaters.

PONDS AND SWAMPS.

No sheets of fresh water worthy of the name of lakes are found within the New Plymouth Subdivision. A few small ponds exist, which may be classified as (*a*) those occurring in sand-dune areas, (*b*) those which possibly owe their origin to local subsidence.

(*a*.) The only case of a pond formed by the damming-up of streams by drifting sand is the small lagoon occurring in the sandhills about one mile and a quarter south-west of Paritutu.

* For general information concerning New Zealand dune areas the reader may consult the comprehensive "Report on the Dune-areas of New Zealand" (C.–13, 1911), by L. Cockayne. This report gives the area of the dunes between New Plymouth and the Mokau River as 11,621 acres, but this is apparently a misprint for 1,621 acres.

(*b.*) There are at present two examples of ponds occupying possible areas of subsidence—namely, the Rotokare or Ratapihipihi Lagoon, about two miles south of New Plymouth, and the pond situated close to the Richmond Road, about three-quarters of a mile from the southern boundary of the subdivision. As will be explained in Chapter II, there are a number of small basins within the subdivision which apparently owe their existence to local downfaulting, probably due to the removal of soluble matter from the underlying strata. It seems likely that the ponds mentioned above have originated in this way.

SPRINGS.

Small springs at the junction of strata of different permeability are common throughout the subdivision. They are particularly abundant in the rocks of the Onairo and Pouakai Series (for descriptions of rocks see Chapter II), but occur also in the later accumulations, as, for example, along the contact of the wind-blown sands with more consolidated débris. In this latter case the springs deposit considerable quantities of iron-oxide, which is also precipitated in less amount from water draining out of Pouakai rocks. Springs issuing from the Onairo rocks are not, as a rule, in any way remarkable. At German Hill, however, to the south of the subdivision—where Onairo rocks are possibly close to the surface (see p. 16)—a considerable precipitation of calcareous sinter has taken place from the water of a number of small springs. Water from one of these springs yielded the following analysis (results expressed in parts per 100,000) :—

Sodium-chloride	10·18
Potassium-chloride	5·54
Sodium-sulphate	18·17
Magnesium-bicarbonate	54·44
Calcium-bicarbonate	73·93
Iodides	Nil
	162·26
Sulphuretted hydrogen	0·30

Remarks on the water issuing from two of the petroleum-wells near New Plymouth will be found in Chapter III.

COAST-LINE.

The coast-line of the New Plymouth Subdivision exhibits no indentations except the mouths of the larger streams in the eastern portion, which are tidal for a short distance. From the western boundary of the subdivision to the Sugar-loaves the coast-line is occupied by low sand-dunes, which again occupy the sea-frontage from the mouth of the Henui to the mouth of the Waitara. At Moturoa the coast-line is broken by the Sugar-loaves, and between Waitara and the eastern boundary of the subdivision, save where indented by the mouths of the larger streams, is fronted by vertical cliffs seldom more than 100 ft. in height. These cliffs are formed of Miocene sedimentaries capped by pyroclastic rocks.

The sea is rapidly encroaching on the last-described portion of the coast-line. Abundant evidence of this is furnished by the rapid destruction of the sites of numerous old Maori pas or fortified villages, which, within the memory of many persons, have dwindled to a mere vestige of their former size.

The coast-line of the New Plymouth Subdivision therefore exhibits all the characteristics of an area which has undergone recent elevation. A still more recent slight depression is evidenced by the sunken mouths of the streams in the eastern part of the subdivision. No evidence of such depression, however, is forthcoming in the western part of the area.

EXPLANATION OF SOME OF THE PHYSIOGRAPHIC FEATURES.

A glance at the general map shows very clearly that the accumulation of the volcanic matter which forms Mount Egmont and the Pouakai Range has exercised a marked influence on the drainage-system of the area. As a result of the building-up of the great volcanic cone of Egmont, many small streams, draining its sides and radiating outwards from its summit, have originated. On the western, northern, and southern sides of the mountain these streams follow an almost straight course to the sea. The watercourses draining the eastern slopes of the mountain are generally tributary to streams which were in existence before Mount Egmont. Below their junction such streams turn sharply to north or south and flow towards the sea. The most striking example of this is the Manganui River, which flows in a general easterly direction from the mountain to its junction with the Waitara River, which thence follows a northerly course to the sea.

There is little doubt that the extravasation of the great amount of volcanic material which forms Mount Egmont and the Pouakai Range, together with the institution of so many rapidly flowing streams bearing abundant loads of sediment, exercised a marked influence in the deflection of the slowly flowing muddy streams that drained the country to the east. This influence is clearly seen in the case of the Waitara and Wanganui rivers, and was also probably operative on the Mokau River, which in the lower part of its course exhibits a decided turning from a south-westerly to a westerly direction—a tendency which may have been more marked in earlier times before the removal by marine denudation of the greater part of the low coastal plain, and the consequent shortening of the course of the river.

The writer is unable to propound a satisfactory explanation of the Tapuae-Manganui Ridge—*i.e.*, of the portion lying between the mouth of the Tapuae Creek and the Manganui River. For convenience the term has sometimes been used more generally to include also the north-eastern extension of this ridge (see above, p. 5). The view that the low-lying country to the south of this ridge represents the former bed of a westerly-flowing river (most probably the Waitara), which was subsequently diverted, as described above, by the products of the Mount Egmont volcano, is favoured by the following considerations: (*a*) the existence of marked terraces, which from their inclination towards the sea would appear to have been formed by a river, at the foot of the Kaitaki or Patua Range on the southern border of this low country; (*b*) the frequent occurrence in the volcanic débris, found at the seaward termination of the low country, of water-worn pebbles of quartzite, grauwacke, argillite, &c., which would seem to have been conveyed thither by a river long enough to reach back to the beds of conglomerate occurring abundantly in the Miocene rocks east of the subdivision.

The low-lying country to the north of the Tapuae-Manganui Ridge might similarly be ascribed to the erosive action of the Mokau River. In this case the ridge would be a residual of erosion. An insuperable objection to this view, however, is the behaviour of the numerous streams which were formed subsequently to the appearance of Mount Egmont. These streams, after crossing the southern lowlands, cut straight through the ridge on their way to the sea.

A theory which offers an easy but unsatisfactory way out of the difficulty is that the ridge marks the scarp of a fault by which the country to the south has been thrown down, and that the faulting took place with sufficient slowness to allow the streams to keep pace with it in their downcutting. Such a theory as this applied to a district of heavy rainfall and rapid denudation, in the absence of any structural data, must be viewed with distrust.

Literature.

The following list includes, so far as the writer is aware, all the publications of importance bearing on the geology of the New Plymouth Subdivision or its neighbourhood. The following abbreviations are employed: Rep. G.S.—"Reports of the Geological Survey of New Zealand"; Trans.—"Transactions and Proceedings of the New Zealand Institute"; Q.J.G.S.—"Quarterly Journal of the Geological Society." A capital letter followed by a figure—thus, C.–3—refers to a New Zealand parliamentary paper.

1843. Dieffenbach, E.: "Travels in New Zealand." Chapters vii and viii, vol. i, contain an account of geological and other features of Taranaki.

1850. Mantell, G. A.: "Notice of the Dinornis," &c. Q.J.G.S., vol. vi, p. 319. "Infusorial Earth of Taranaki." *Ibid.*, p. 332. Identifies a number of diatoms from near New Plymouth.

1866. *New Zealand Gazette*, 29th June: Sketch of Geology of the District. Probable that some surface indications of oil are due to decomposition of superficial lignitic lodes. Volcanic deposits were accumulated under the sea, and are at least 2,000 ft. thick, conformably underlain by 2,000 ft. or more of sedimentary strata which overlie the brown-coal formation which is the ultimate source of the oil. Brown-coal formation extends under Mount Egmont in patches deposited in hollows in the Palæozoic rocks. Since oil originates in Tertiary strata, the district shows some resemblance to petroleum-wells of Italy, the Crimea, and Asia Minor. From analogy with these fields, the author (? Hector) considers the proper place to prospect for petroleum is towards the Mokau River. Boring near Moturoa will never give large supplies of oil. Oil contains too large a proportion of carbon to render it altogether suitable for illuminating purposes. However, lighter oils may be obtained by boring elsewhere, as has occurred in other parts of the world. Quotes analyses of the oil, which will be found in Chapter III of this bulletin.

1868. Hector, James: "Taranaki District." Rep. G.S. during 1866–67, p. 2. Distinguishes a number of distinct formations between Mokau and New Plymouth. Emphasizes the absence of the alternate beds of sand and clay, which are found in the chief oil districts of the world.

1874. Skey, W.: "On the Mineral Oils of New Zealand." Trans., vol. vi, p. 252. Gives results of examination of oil "from the Sugar-loaves," which is quoted elsewhere.

1879. Skey, W.: "Preliminary Note on the Presence of One or More Hydrocarbons of the Benzol Series in the American Petroleum, also in our Petroleums." Trans., vol. xi, p. 469. Finds that in Taranaki crude petroleum the benzol series is well represented quantitatively.

1879. Hector, James: "Progress Report." Rep. G.S. during 1878–79, p. 20. Brief account of geology of the basin of the Mokau River and of the north-eastern portion of the New Plymouth Subdivision.

1887. Park, James: "On the Geology of the Western Part of Wellington Provincial District and Part of Taranaki." Rep. G.S. during 1886–87, p. 24. On page 42 short account of the geology of the district between New Plymouth and Waitara.

1887. Park, James: "On the Upper Wanganui and King-country." Rep. G.S. during 1887–88, p. 167. Deals mainly with country to east of the subdivision, but on page 179 is brief mention of the topography of the Waitara district.

1888. McKay, A.: "On the Discovery of Metalliferous Rocks in the Patua (Kaitaki) Range, New Plymouth." Rep. G.S. during 1887–88, p. 35. Concludes that the deposits are most probably surface sinters. None of the samples yielded more than a trace of silver. One contained 6·42 per cent. of copper.

1889. Hutton, F. W.: "The Eruptive Rocks of New Zealand." Journal and Proceedings of Royal Society of N.S.W., vol. xxiii, p. 102. Contains a description of various igneous rocks from the subdivision and its neighbourhood. Further reference to this paper is made in Chapter II, p. 22.

1896. *The Iron and Coal Trades Review*, 10th July, 1896: "The Ironmaking Resources of Australasia—1, New Zealand." Deals largely with the Taranaki ironsand; gives an account of attempts to smelt the ore, and considers that the deposits present great economic possibilities.

1897. *Electrician*, 17th September, 1897: "The Magnetic Properties of Annealed Wrought Iron manufactured from the Ironsands of New Zealand." The results show that the wrought iron prepared from Taranaki ironsand by Mr. E. M. Smith's patent process is normal in its magnetic qualities under high and low magnetizing forces.

1898. McKay, A.: "Petroleum (Report of Government Geologist on the Present Condition of and Future Boring for) at New Plymouth." C.–9A. Describes the state of the New Plymouth Company's (Samuel's syndicate) workings, which at the time had proceeded as far as No. 6 bore. Concludes that there are oil horizons at 900 ft. and 2,000 ft. approximately; that a further 1,000 ft. might be bored without reaching carbonaceous beds likely to, or capable of, affording the oil stored at higher levels.

1898. Hutton, F. W.: "Corrections in the Names of some New Zealand Rocks." Trans., vol. xxxi, p. 484. Reference to this paper is made in Chapter II.

1899. McKay, A.: "Report on Petroleum at New Plymouth, Taranaki." C.–9, p. 3. Gives a history of the search for oil in the district, and extracts from reports on the prospects of the district. Considers that boring operations have proved existence of oil at a depth sufficiently great to preclude the possibility of its derivation from superficial carbonaceous remains. But whether the oil-bearing strata are a continuation of the Mokau coal-beds is impossible of proof, since these would be 5,000 ft. below the surface and beyond the reach of boring.

1899. C.–9, p. 138. Abstract of McKay's Report (C.–9, p. 3).

1899. C.–2, p. 13. Reference to successful tests of Taranaki ironsands.

1906. Supplement to *Taranaki Herald* of 19th May: "Petroleum in Taranaki." An account of the earlier attempts to obtain oil in the district.

1907. Maclaurin, J. S.: "Fortieth Annual Report of the Colonial Laboratory," p. 34. Analysis of crude oil from New Plymouth. The sample is shown to resemble Russian rather than American oil.

1907. Hill, H.: "Oil-wells and Oil Prospects along the East Coast." Trans., vol. xxxix (1906), p. 509. Mainly deals with Poverty Bay oil, but also contains some reference to Taranaki.

1908. Marshall, P.: "Distribution of the Igneous Rocks of New Zealand." Rep. Aust. Ass. Adv. Sci., vol. xi, p. 375.

1909. Bell, J. M.: "Preliminary Report on the Taranaki Oilfield." C.–14. Contains a brief account of the general features, geology, oil-boring operations, and oil and gas indications of the subdivision and its neighbourhood.

1910. Clarke, E. de C.: "Geological Survey of Part of the New Plymouth Subdivision." C.–9, p. 19. Contains a brief tentative account, mainly of the geology and oil indications of the eastern portion of the subdivision. Concludes that there is as yet no geological evidence warranting the definite location of bore-sites.

1910. *The Mining Journal*, 11th, 18th, and 25th June: "The Oilfields of New Zealand." The issue of 18th June gives a brief but good summary of the history of oil-prospecting, and of Hector's, Park's, and McKay's views as to the geology of the area. Considers New Plymouth district to be the most promising in New Zealand, and concludes that the most hopeful horizon at Moturoa is at 2,000 ft. or more, but that these oil-bearing strata might be obtained at less depths towards Mokau or by going inland from New Plymouth, and that much field examination and prospecting has still to be done before existence of a payable oilfield in Taranaki can be regarded as proved.

CHAPTER II.

GENERAL GEOLOGY.

Outline of Geology.

General Sequence of Formations.

The oldest rocks exposed in the New Plymouth Subdivision are a series of claystones, sandy claystones, sandstones, and conglomerates, to which from palæontological considerations a Miocene age is assigned. The name "Onairo," that of a stream in the eastern portion of the subdivision, in the watershed of which this series is extensively developed at the surface, has been given to these Miocene strata.

Overlying the Onairo Series, generally in apparent unconformity, is a considerable thickness of volcanic débris, made up of fragmentary matter of all grades of coarseness, from boulders 10 ft. in diameter to the finest ash. Interbedded with this material is a variable amount of vegetable matter, often only slightly carbonized, and sometimes in quantities great enough to merit the name of "buried forest." To this series the name "Pouakai" is given, it being considered to have originated mainly from the volcanic mountain of which the Pouakai Range forms the denuded remains. The age of the Pouakai Series is Miocene or younger, but owing to the absence of recognizable fossils cannot be definitely fixed.

Unconformably overlying the Pouakai Series are the alluvial deposits in the valleys of the various streams, together with the wind-blown sands forming the dunes along the coast-line, and various marine and fluvio-marine accumulations. These may be classed as Pleistocene and Recent in age.

General Account of the Structure of the Formations.

The finer-grained rocks of the Onairo Series are fairly well consolidated, but never at all altered, save that local hardening owing to the segregation of carbonate of lime or iron-oxide may occur. Wherever exposed within the subdivision they are either horizontally bedded or very gently undulating. No faulting has been observed within the limits of the area under review, but to the northward a few very slight and local faults have been recognized.

The Pouakai, Pleistocene, and Recent rocks are only exceptionally, and then but slightly, consolidated. The stratification of these rocks has remained practically horizontal since the time of their deposition.

Geological History.

The probable succession of events since Onairo times has been sufficiently dealt with in the section on physiography.

Comparison of Classification of Rocks with those of Previous Investigators.

On the next page is a tabular comparison of the classification adopted in this bulletin with the sequence as determined by Hector and Park.

Hector's Classification (Rep. G.S. during 1866–67 and 1878–79).			Park's Classification (Rep. G.S. during 1886–87).			Classification of this Bulletin.		
Age of Series.	Character and Subdivisions of Series.	Localities in which Subdivisions of Series are developed.	Age of Series.	Character and Subdivisions of Series.	Localities in which Subdivisions of Series are developed.	Age of Series.	Character and Subdivisions of Series.	Localities in which Subdivisions of Series are developed.
Cretaceo-tertiary	Grey marls, chalk marls, and coal-seams	Mokau River.	Cretaceo-tertiary	(*d.*) Blue sandy clays, alternating with beds of marlstone	Panirau (on Mokau River).	Miocene ..	*Onairo Series*: Sandstones, claystones, and limestones, with coal-seams (only cursory attempt to determine order of succession has been made)	Mokau River and coast north of Tongaporutu.
	Unconformity.			(*c.*) Green sandstones and dark marly clays, with coal-seams	Patokatoka (on Mokau River).		Claystones and sandstones, with occasional conglomerates	Eastern portion of subdivision.
Eocene ..	Nummulitic limestone	Mokau River.		(*b.*) Foraminiferous limestone	Patokatoka (on Mokau River).		*Unconformity, probably representing no great lapse of time.*	
	Tufaceous greensands and breccias, passing northward into "solid trachyte flŏes."	North end of White Cliffs, and thence northwards.		(*a.*) Tufaceous greensands and crumbling marly clays	Mokau River and Tongaporutu to Mokau Heads.	Miocene and Pliocene	*Pouakai Series*: Lava-flows ..	Sugar-loaves and (probably) Pouakai Range.
				Unconformity.			Fragmental rocks (almost entirely igneous)	Western portion of subdivision.
Lower Miocene (Pareora)	Clay marls	From a few miles north of Waitara to White Cliffs.	Upper Miocene	Blue clays, with gritty shell-beds	Onairo.		Lava-flows and fragmental igneous material	Mount Egmont.
				Unconformity.		Pleistocene and Recent	Marine, fluvio-marine, and æolian deposits of gravel, sand, and mud	Sea-coast and valleys of streams throughout the area.
..	Volcanic rocks of Mount Egmont	Westwards and southwards from a few miles north of Waitara.	Younger Pliocene or later	(*d.*) Mount Egmont ..	Mount Egmont.			
				(*c.*) Volcanic tufas and agglomerates	Widely developed in Taranaki.			
			Pleistocene and Recent	(*b.*) Drift formation ..	New Plymouth to Mokau.			
				(*a.*) Blown sand and river-terraces	..			

The Onairo Series.

Introductory.

The Onairo Series consists of a succession of claystones, sandy claystones, and sandstones, with occasional bands of conglomerate. The base of the series is nowhere seen within the subdivision, nor has it been reached in boring for oil near New Plymouth, though one of the boreholes has already passed through more than 3,500 ft. of strata belonging to the series.

As shown in the table on page 14, Hector and Park divided the strata described here into at least two unconformable series. The combined thickness of these series Hector estimated at 4,000 ft. or 5,000 ft. From his own observations the writer considers that the total thickness of the series is probably more than 5,000 ft. The series is, on palæontological grounds, correlated with strata, extensively developed in other parts of the Dominion, to which a Miocene age has generally been assigned.

General Distribution.

The Onairo Series is exposed at the surface, or with a coating of the volcanic débris of the Pouakai Series so thin as to be negligible, over an area of about 94·4 square miles in the eastern portion of the subdivision. The approximate boundary of this area is indicated on the geological map of the Waitara Survey District, and runs in general slightly east of north from a point four miles and a half east of Huirangi Trig. Station to the eastern margin of the subdivision. It must, however, be understood that this demarcation is a more or less arbitrary one, marking approximately the line along which the thickness of the volcanic débris becomes insignificant. West of this line the rocks of the Onairo Series are to be found outcropping in almost every gully as far as the Waitara River.

On the coast-line they occur continuously (underlying the Pouakai Series) as far west as a spot about three-quarters of a mile east of Trig. Station IX (Waihi), while at Waitara itself the records of the bores of two artesian wells at the freezing-works show that the Onairo Series, here consisting of claystone, is about 100 ft. below the surface, and is overlain by rocks of the Pouakai and Pleistocene and Recent Series. Immediately west of the Waitara River a few occurrences of the Onairo Series have been found. Again, near the western boundary of the subdivision, at Trig. Station XXVIII (Burton's Hill), at a height of between 400 ft. and 500 ft. above sea-level, several outcrops of micaceous sandy claystone containing a few Miocene fossils are found near the head of a small northward-flowing stream. In the sea-cliffs near the western boundary of the subdivision masses of well-bedded claystone, sometimes as much as 5 yards in diameter, are found in the agglomerates or breccias of the Pouakai Series. These are especially noteworthy (*a*) at the mouth of Waireka Creek (where also small inconstant beds of quartz and quartzite pebbles occur), (*b*) at a point about 20 chains east of the mouth of Waireka Creek, (*c*) to the west of the mouth of Waireka Creek, (*d*) at the mouth of the very small creek running out just on the New Plymouth side of Tokatapu Rock, (*e*) at the bathing-shed near the railway-station at New Plymouth. Beyond the western boundary of the subdivision inclusions of claystone in the agglomerate become more numerous, especially between Waikukakuka and Tokataratara, in which neighbourhood the large blocks of claystone show distinct stratification seemingly coincident with that of the accompanying beds of volcanic débris. At about 20 chains north-east of the mouth of Tapuae Creek is a small but remarkable patch of limestone containing fossils apparently differing from those found elsewhere in the Onairo Series.* Smaller lumps of

* Unfortunately these specimens have been mislaid. The writer has been unable in the time at his disposal to obtain more for purposes of description. A cursory field-examination conveyed the impression that species characteristic of the Scinde Island (Napier) limestone were represented.

claystone are to be found in a quarry on a creek about a quarter of a mile south of Trig. Station D (Elliot) in Westown, near New Plymouth. They also appear to be abundant a quarter of a mile farther up this stream. The finding of a fossil *Ostrea* in the bed of the Henui River seems to point to the occurrence of some Onairo rocks in the watershed of this stream. Blocks of claystone are also said to outcrop at German Hill, to the south of the subdivision. Although both localities have been examined by the writer, neither of these occurrences has been confirmed.

Records of the boreholes put down inland and near New Plymouth show that the Onairo Series underlies the volcanic débris of the Pouakai Series throughout the subdivision. The upper surface of the former series rises gradually towards the interior, being, on the average, 200 ft. below sea-level at New Plymouth and 300 ft. above in the neighbourhood of Inglewood.

Petrology.

The rocks of the Onairo Series consist of claystones, sandy claystones, sandstones, and conglomerates.

(1.) *Claystones and Sandstones.*—Within the New Plymouth Subdivision the greater part of the series consists of soft calcareous claystones, which are frequently somewhat sandy, and occasionally pass into rather incoherent, often abundantly micaceous, sandstones. It may be said in general that these finer-grained rocks grade imperceptibly into one another. No success attended the attempt to trace any particular band of sandstone or claystone for more than a short distance. Towards Mokau an extensive development of sandstones, with limestone and coal, is found. Small coaly partings occasionally occur in the finer-grained rocks of the Onairo Series, and are especially noticeable near the gravel-quarry on the Okoke Road near its junction with the Mokau Road. The claystones and sandstones are often fossiliferous. The rocks under discussion frequently, especially in the south-east corner of the subdivision, contain hard calcareous nodules which have been formed by the segregation of carbonate of lime during, or after, the consolidation of the enclosing strata. Within the subdivision these concretions usually have a spherical or ellipsoidal form, and are disposed in lines parallel to the planes of stratification. On the east side of the valley of the Mangahewa Stream, however, two bands of such concretions are seen to be distinctly inclined to one another, the upper band cutting obliquely across the bedding of the claystone. In the cliffs bordering the sea on the northern boundary of the subdivision the concretions are irregular in shape, and have their long axes at right angles to the planes of stratification. Similar fantastically shaped nodules are to be seen in the cliff just south of the mouth of the Mohakatino River. In a small stream entering the headwaters of the Urenui River from the west the concretions are prismatic in shape. The concretions are rarely united to form continuous bands. They are the hard streaks frequently referred to in records of bores.

Small crystals of pyrite are almost always to be found in the claystones and sandstones. The following is an analysis of a typical sample of Onairo claystone from the cliffs in the Waitara River, near the southern boundary of the subdivision :—

Silica (SiO_2)	60·95
Alumina (Al_2O_3)	18·19
Ferric oxide (Fe_2O_3)	4·11
Lime (CaO)	3·42
Magnesia (MgO)	2·24
Alkalies (K_2O and Na_2O)	5·30
Carbonic anhydride (CO_2)	0·90
Moisture and organic matter	4·89
	100·00

The following analysis* of "clay from Urunui [Urenui]" is of interest, as the clay (almost certainly of the Onairo Series) was that which the late Mr. E. M. Smith sometimes used in iron-smelting (see *postea*, p. 50):—

Silica	62·93
Iron-oxides	8·03
Iron-sulphides	Traces
Manganese	Traces
Alumina	16·48
Lime	2·82
Magnesia	1·27
Alkalies	3·69
Carbonic acid	0·73
Sulphuric acid	0·23
Titanic acid	Traces
Water and organic matter	3·82
	100·00

2. *Conglomerates.*—The conglomerates occur in the finer sediments described above, as bands, commonly about 1 ft. in thickness, but varying in different localities from a few inches up to 10 ft. or 12 ft. The conglomerates are, as a rule, little consolidated, save where cemented by calcareous matter derived from fossil remains, which they very frequently contain. The fragments of which the conglomerates are composed vary from minute pebbles to small boulders that but rarely reach 6 in. in diameter. All are well-rounded and water-worn.

A study of hand-specimens and of microscopic sections of pebbles from the conglomerates shows that the usual constituents are quartz, quartzite, and jasperoid argillite. Fragments of grauwacke, and possibly of diorite, are also rather common. The material of which the conglomerates are composed is evidently derived from a complex of old sedimentaries and intrusives lying to the east of the area under review, which makes up the structural axis of the North Island. The sedimentaries of this complex were at one time usually referred to the Maitai Series, of supposed Carboniferous age, by the staff of the Geological Survey, but during recent years the age of the rocks placed in the Maitai Series has been generally considered an open question.

Structure.

Since the Onairo Series contains apparently the chief petroliferous strata of the area under consideration, the main object of the recent geological survey was to arrive at a knowledge of the structure and arrangement of the various members of the series, with a view to the location of anticlines and synclines, in which, according to the very generally accepted "anticlinal" theory, the oil might be expected to have accumulated. With this object, as many reliable strikes and dips as possible were noted and plotted on the geological maps. As a rule, the finer-grained rocks of the Onairo Series exhibit fairly distinct lines of stratification. A local exception to this rule is found in the fine claystones exposed in the upper waters of the Onairo Stream, which are singularly devoid of bedding-planes.

As already noticed, the streams of the subdivision flow nearly to their headwaters through alluvial deposits. Therefore few outcrops of Onairo rocks are to be found in the actual watercourses, except near their sources. It thus follows that the majority of the strikes and dips recorded had to be obtained on the sides of spurs some distance from the streams, on faces exposed by landslips, or in road-cuttings and quarries. It seems probable, therefore, that, though care was taken to record only those observations made in strata undisturbed by surface-slipping, a certain amount of sagging may have taken place along large

* "Fifth Annual Report of the Colonial Museum and Laboratory," 1870, p. 12.

1522.

exposed faces of such soft strata as those under consideration. When the prevailing low angle of dip is remembered, it is evident that the liability to error in recording the stratification is great.

A careful plotting of the most reliable strikes and dips has failed to reveal the existence of any persistent anticlines and synclines. The strata under consideration dip to all points of the compass, but on summarizing it is found that the westerly dips outnumber the easterly in the proportion of three to one. The more exact directions of the westerly dips are divided almost equally between south-west, west, and north-west, but in the south-east portion of the subdivision a slightly preponderant number are to the south-west, while in the north-east portion the dip is more usually to the north-west. The dips are always at low angles, usually less than 10°, only ten or twelve instances of dips of 15° or more, and about the same number of dips at angles between 10° and 15°, having been observed. Of these higher dips a few more are westerly than easterly. It thus appears that the rocks of the Onairo Series are arranged in gently undulating fashion, but are in general dipping in a westerly direction. There is some indication that they form the western end of a westerly-pitching anticlinorium, the axis of which runs in a north-west and south-east direction.

Evidence obtained towards Mokau, beyond the eastern limits of the subdivision, shows that the calcareous claystones which predominate in the New Plymouth Subdivision are underlain in descending order by (1) rapidly alternating sandstones and claystones, (2) sandstone in thick beds together with limestone and occasional coal-seams.

Outside the subdivision, from the White Cliffs to Awakino, small local faults in the rocks of the Onairo Series are of fairly frequent occurrence. The largest faults observed were in the Maryville Coal-mine, on the Mokau River, where one or two quite local dislocations with a maximum throw of 6 ft. to 8 ft. have been disclosed in the workings. Within the subdivision no actual faults were observed, but in seven localities the topography seems to indicate that subsidence of small blocks of strata including Onairo rocks has occurred. These localities are specially indicated on the maps, and are situated—(1) in the acute angle formed by the junction of the Richmond and Ackworth Roads; (2) on the west side of the Richmond Road, about half a mile beyond its junction with Lincoln Road; (3) near the Mangahewa Road, about half a mile from its junction with the Otaraoa Road; (4) at the headwaters of the Mangaonga Stream; (5) near the headwaters of the Mangaonga Stream; (6) just outside the eastern boundary of the subdivision, about half a mile north of Junction Road; (7) at the Rotokare or Ratapihipihi Lagoon, two miles south of New Plymouth. No undoubted occurrences of Onairo rocks *in situ* are found near Nos. (1), (2), (3), and (7) of the localities mentioned. The depressions may therefore be due to subsidences in the overlying volcanic débris of the Pouakai Series alone. In the other three localities mentioned there can be little doubt but that local basin-faulting in which the Onairo rocks were concerned has recently taken place. There is apparently no structural relationship or community in origin between these depressions, the main structural features of the Onairo rocks, and the occurrence of gas or oil indications.

Interrelationship of the Different Members of the Series.

Since the conglomerate bands already described are the only beds in the Onairo Series with distinctive petrological characters, the writer attempted by means of repeated observations of strike and dip and barometric heights to establish for them definite horizons in the series. It may be said in general that the conglomerates appear to occur at two different levels in the series, separated by about 200 ft. of the finer sediments.

In his reports on the Taranaki District Hector divided the Onairo Series into three distinct formations of Cretaceo-tertiary, Eocene, and Lower Miocene ages. He considered the unconformity between the Cretaceo-tertiary and the Eocene series to occur on the Mokau River, and that between the Eocene and Lower Miocene to be seen near the northern end of

the White Cliffs.* In his earlier report he classed the rocks, which he later referred to the Lower Miocene, as older and newer Tertiary, separated by a marked unconformity at the mouth of the Omera (Onairo), and with the newer Tertiary he included the greater part of the Pouakai Series of this report. In his later paper, however, no mention is made of this unconformity, and his classification is as stated above. Further notes regarding this point will be given later. In this, as in most other important points, the later observers, McKay and Park, appear to be in general agreement with Hector. Park in his report† divides the rocks in question into Cretaceo-tertiary and Upper Miocene, and, though he does not describe it, shows in his map an unconformity between the two series at Tongaporutu. He makes no reference to Hector's unconformity between Pliocene and Miocene at Onairo.

The writer has been unable to find the evidence for the unconformity which according to the above geologists separates the lowest part (Cretaceo-tertiary beds) of the Onairo Series from the overlying portion. Apparent unconformities may sometimes be recognized at various horizons, as, for example, between a sandy claystone and a quartzose conglomerate at Corkill's quarry, in the south-eastern corner of the subdivision, but these are due to current bedding.

The following brief account of the strata forming the lower portion of the series under discussion, which are exposed mainly along the sea-front between Pukearuhe and Awakino, may be of interest.

In the neighbourhood of Tongaporutu the claystones and sandy claystones that form the sea-cliffs to the south tend to pass into soft sandstones arranged in beds as much as 25 ft. in thickness. The sandstones are interbedded with the claystones, and represent the same period of sedimentation. Farther north, between Rapanui and Awahaehae streams, the low cliffs are composed of an impure green sandstone, overlying which in apparent conformity is claystone. In the neighbourhood of Kawau Pa the rocks consist of 6 in. beds of clay separated by thin partings of sand, and overlying all is a bed of yellow sandstone about 7 ft. thick. About two miles farther on beds of greensand are separated by thin partings of clay, and at the Mokau Heads a yellow sand overlies a claystone in which is a thin layer of pebbles, apparently andesite.

Between the Mokau Heads and the Awakino Heads beds of sandstone about 18 in. in thickness alternate with seams of clay about 3 in. thick. These are underlain at the south Awakino Head by a fine well-bedded grit, containing abundant hornblende crystals, which in turn is underlain by a bryozoan limestone.

On the Awakino – Te Kuiti Road, about half-way up the Taumatamaere Hill, decomposed grauwackes and argillites containing apparently Triassic fossils are overlain by sandy claystones with abundant Miocene fossils. It seems probable that these claystones underlie the limestones mentioned above.

The section obtained by following the Mokau River as far as the Maryville Coal-mine requires much careful examination, but, so far as the writer could observe, the general sequence seen between Mokau and Awakino holds good, save that there is on the Mokau an extensive development of coal-seams, with accompanying sandstones, in the strata underlying the limestone.

Palæontology.

Though seldom very abundant, fossils can be found in most exposures of the Onairo rocks. They are most numerous in the bands of the upper conglomerate horizon exposed in the headwaters of the Urenui River and its tributaries, and in the sandy claystone which forms the sea-front between Urenui Township and the mouth of the Mimi River. The following list includes, so far as is known, all the specifically identified fossils which have been

* Rep. G.S., 1878–79, p. 21. [It is not quite clear whether Hector considered an unconformity to exist at the White Cliffs or not.—P. G. M.]

† Rep. G.S., 1886–87, vol. xviii, p. 57. On p. 60 Park says that "there is no stratigraphical break in the sequence of the Tertiary strata from the lowest to the highest beds."

found in or near the New Plymouth Subdivision either by the writer or by previous investigators. The names are given in the first column, whilst in the second is entered the name of the first collector to report the species from the subdivision or its neighbourhood. In the third column is placed the range of the species. This is taken wherever possible from an unpublished summary* of the Tertiary formations in New Zealand in the possession of the New Zealand Geological Survey. When the species is not mentioned in that paper the range is generally taken from Hutton's Catalogue of the Tertiary Mollusca and Echinodermata of New Zealand.

Species.	First Collector.	Range.
Anthozoa.		
Flabellum laticostatum Tenison-Woods ..	Clarke ..	Upper Oamaru.
Trochocyathus mantelli Milne-Edwards ..	Clarke ..	*Middle Oamaru (Waikouaiti beds).
Pelecypoda.		
Nucula nitidula Adams	Park ..	Recent.
Solenella australis Zittel	Park ..	Upper Oamaru and Wanganui.
Cucullæa alta Sowerby	Clarke ..	*Lower Oamaru (Waihao greensands).
Limopsis (*Trigonocœlia*) *insolita* Sowerby ..	Clarke ..	*Upper Oamaru (Pareora beds).
Glycimeris (*Pectunculus*) *laticostatus* Quoy..	Park ..	Oamaru–Recent.
G. (*Pectunculus*) *globosus* Harris	Clarke ..	*Upper Oamaru (Pareora beds).
Pecten fischeri Zittel	Clarke ..	Upper Oamaru.
Pseudamusium (*Pecten*) *hochstetteri* Zittel ..	Clarke ..	Upper Oamaru.
Lucina divaricata Lamarck	Park ..	Oamaru–Recent.
Cardium striatulum Sowerby	Park ..	Upper Oamaru–Recent.
Dosinia grayi Zittel	Park ..	Upper Oamaru and Wanganui.
Cyclina dispar Hutton	Park ..	Doubtful.
Venus (*Chione*) *mesodesma* Quoy ..	Park ..	Upper Oamaru–Recent.
V. (*Chione*) *stutchburyi* Gray	Park ..	Upper Oamaru–Recent.
Meretrix (*Cytherea*) *acuminata* Hutton ..	Clarke ..	Upper Oamaru.
Tellina deltoidalis Lamarck	Park ..	Pleistocene and Recent.
Mytilicardia excavata Deshayes	Park ..	Wanganui and Recent.
Mactra æquilatera Reeve	Park ..	Pleistocene and Recent.
Zenatia acinaces Quoy	Park ..	Upper Oamaru–Recent.
Teredo heaphyi Zittel	Clarke ..	*Lower Oamaru (Waihao greensands).
Scaphopoda.		
Dentalium ecostatum Kirk	Park ..	Upper Oamaru and Wanganui.
D. giganteum Sowerby	Park ..	*Middle Oamaru (Waikouaiti beds).
D. nanum Hutton	Park ..	Wanganui.
Gastropoda.		
Crepidula incurva Zittel	Park ..	Upper Oamaru.
Natica (*Mamilla*) *ovata* Hutton	Park ..	Upper Oamaru and Wanganui.
N. vitrea Hutton	Park ..	Wanganui–Recent.
Turritella (*Zaria*) *tricincta* Hutton (= *T. rosea* of Mantell)	Park ..	Upper Oamaru–Recent.
Cassidaria sulcata Hutton	Park ..	Upper Oamaru.
Struthiolaria tuberculata Hutton ..	Park ..	Upper Oamaru.
Buccinum robinsoni Zittel	Park ..	Upper Oamaru.
Cominella maculata Martyn, var. *b* ..	Park ..	Upper Oamaru–Recent.
Siphonalia nodosa Martyn	Clarke ..	Upper Oamaru–Recent.
Ancilla australis Hutton	Park ..	Upper Oamaru–Recent.
Pleurotoma tuberculata Kirk	Park ..	Wanganui.

* Drawn up mainly by Professor Park. Species marked with an asterisk (*) are regarded by this author as characteristic of the horizon to which they are assigned.

Age and Correlation.

From the evidence given on previous pages it appears that the Onairo Series consists of a conformable succession of rocks. A consideration of the ranges of the fossil species enumerated in the preceding section leads to the conclusion that the series is of Oamaru (Miocene) age. In petrological character and in fossil-contents the rocks in question show a very close resemblance to strata in the northern part of the South Island to which a similar age has been assigned.*

The Pouakai Series.

Introductory.

The Pouakai Series consists of a succession of beds, generally of fragmental volcanic material, sometimes water-worn, but usually angular or subangular, with which are interbedded, in places, rather extensive lignitic deposits and inconsiderable layers of thoroughly water-worn pebbles of quartz, quartzite, grauwacke, and argillite. In one place have been found rare fragments of baked or reddened claystone† of the Onairo Series. The flow rocks, probably of somewhat earlier date, which form the Sugar-loaves near New Plymouth are also included in this series. From data derived from the records of various bores, together with a consideration of the height of the country composed of the rocks of this series, the writer estimates that within the subdivision it has a maximum thickness of about 700 ft.

General Distribution.

The Pouakai rocks may be regarded as covering an area of about 98·6 square miles within the subdivision, though a thin covering of volcanic material extends almost to the eastern and south-eastern boundaries, where, on the geological map, it is not represented. Further details regarding the distribution of the Pouakai rocks have already been given in dealing with that of the Onairo Series (pp. 15, 16).

Structure and Interrelationship of the Different Members of the Series.

The rocks of the Pouakai Series are horizontal, occasional apparent departures from this rule being due to false or current bedding. In general it may be stated that the lower part of the series contains both the more coarsely grained material and the lignitic deposits which are usually, though not invariably, absent from the upper portion of the series. The beds of water-worn pebbles of quartz, quartzite, &c., are found apparently only at the base of the series. The conical hills around Inglewood and near Lepperton, of which mention has already been made, consist usually, but not invariably, of large angular boulders irregularly mixed with finer volcanic material, generally showing a rude bedding with predominant dip to the south-east.

A good idea of the succession of beds in the Pouakai Series is obtained by an examination of the coast-line between New Plymouth and the mouth of the Oakura Stream, about two miles and a half south-west of the western boundary of the subdivision. In the low cliff forming the sea-front at New Plymouth well-bedded volcanic sand is seen to overlie, conformably, a coarse breccia. A few chains east of Paritutu a fine volcanic sand, apparently identical with that just mentioned, unconformably overlies an agglomerate, which in turn, at the base of the eastern slope, unconformably overlies the effusive rocks of which this Sugar-loaf is composed. Breccias and agglomerates, containing in places rocks 10 ft. and more in diameter, but sometimes of only moderate coarseness, form the sea-cliffs to the

* See Bulletin No. 3 (New Series), N.Z.G.S., p. 51.
† The occurrence of these was pointed out to the writer by Dr. J. Wanner, of Bonn University.

south-west of Paritutu; but in many places, more especially between the mouth of the Oakura Stream and the western boundary of the subdivision, coarse agglomerate beds 15 ft. or more in thickness alternate with fine-grained fragmental material. In this neighbourhood, as noted in the section on the Onairo Series (p. 15), inclusions of sedimentary rocks containing Miocene fossils are of frequent occurrence. Small beds of water-worn pebbles of quartz, quartzite, and other rocks also occur. Pebble-beds of this description are, however, most frequent to the north-east of the subdivision, just north of the White Cliffs, where they directly overlie the claystones and sandstones of the Onairo Series.

Inland, wherever the rocks of the Pouakai Series are deeply dissected by watercourses, the same general succession as that exhibited on the coast-line may be recognized more or less satisfactorily, the lower beds containing a much larger proportion of agglomerate than the upper.

Petrology.

(1.) *Igneous Rocks.*—The igneous rocks of the Pouakai Series are generally but little decomposed. Notable exceptions to this rule are the rocks found in Smart Road and elsewhere. These are further described in Chapter III, p. 52.

Numerous samples of the igneous rocks of the Pouakai Series were collected by the writer, but for various reasons microscopic sections of the majority of them are not available for examination at the time of writing. From a megascopic examination, and from the results of chemical analyses, the writer believes that, though they show little or no peculiarity in chemical composition, the Sugar-loaf rocks may on petrological grounds be separated from the rest of the rocks of the Pouakai Series, being (with the exception of those of Mikotahi) characterized by the frequent occurrence of masses of hornblende crystals often several inches in diameter, and by the presence of feldspar crystals which are ½ in. in length. These feldspars are described by Hutton* as sanidine, and he calls the rock a trachyte. Subsequently, however, he stated† that since plagioclase is more abundant than sanidine in the rock, and since the rock is found to contain only 53·43 per cent. of silica, the name should be altered to hornblende-andesite.‡

Specimens of Pouakai igneous rocks collected from other parts of the subdivision, and from some localities a little to the south of it, differ from the Sugar-loaf rocks chiefly in the greater abundance, and more even distribution through the rock-mass, of phenocrysts of ferro-magnesian minerals. A small series of microscopic sections of Pouakai rocks from the agglomerates exposed near the southern boundary of the subdivision, chiefly in the valley of the Waitara River, contains representatives of hornblende- and augite-andesites agreeing very closely in structure with specimens of andesites from the Whangaroa Subdivision.§ The hornblende crystals are dark brown and strongly pleochroic, always surrounded by opaque resorption-bands. In some cases the hornblendes have disappeared completely, leaving their characteristic forms outlined by scattered crystals of magnetite. The augite crystals are pale-yellowish-green in colour and show sharp unaltered margins. A few crystals of hypersthene are occasionally present. In the hornblende-andesites augite is always present, but in some sections showing numerous augite crystals hornblende is absent. Hutton describes‖ hornblende-, augite-, and olivine-andesites from Mount Egmont, and an andesite from the Sugar-loaves in which enstatite is present, but in lesser quantity than augite.

The following are analyses of Pouakai rocks from eleven different localities. For comparison are added three typical analyses of andesites from the agglomerates of supposed

* Journal and Proc. Royal Society N.S.W., vol. xxiii, p. 126.
† Trans., vol. xxxi, p. 484.
‡ I made a section of this rock some years ago in which all the feldspar is triclinic.—P. G. Morgan.
§ Bulletin No. 8 (New Series), N.Z G.S., 1909, pp. 66–67.
‖ Journal and Proc. Royal Society N.S.W., vol. xxiii, pp. 133–42.

Miocene age, which attain a wide distribution in the northern part of New Zealand. It will be seen that the Taranaki rocks analysed show on the average a somewhat lower silica-content. It will also be observed that the rock from Mount Egmont differs in no important respect from the general type of the igneous rocks belonging to the Pouakai Series. On the other hand, the Paritutu rock, originally described by Hutton as a trachyte, is somewhat more acidic than the general type, according to analysis No. 11 in the following table:—

	(1.)	(2.)	(3.)	(4.)	(5.)	(6.)	(7.)
Silica (SiO_2)	58·35	57·60	56·60	56·28	53·95	52·21	52·00
Alumina (Al_2O_3)	20·44	20·35	20·61	18·81	19·63	19·33	18·69
Ferric oxide (Fe_2O_3) ..	2·51	4·24	3·13	5·15	3·17	4·12	6·71
Ferrous oxide (FeO) ..	2·44	2·39	2·30	1·85	4·06	4·81	2·67
Manganous oxide (MnO) ..	0·07	0·24	0·09	0·06	0·20	0·20	0·09
Lime (CaO)	7·45	7·06	5·81	7·72	9·05	9·01	8·72
Magnesia (MgO)	1·63	1·61	1·52	2·27	3·33	3·25	3·65
Potash (K_2O)	2·53	1·88	4·59	2·10	1·84	1·92	1·26
Soda (Na_2O)	4·22	3·55	2·08	3·66	3·38	3·37	2·84
Titanium-dioxide (TiO_2) ..	0·43	0·73	1·20	0·95	0·97	1·05	0·89
Phosphoric anhydride (P_2O_5)	..	..	..	..	0·39	..	n.d.
Carbonic anhydride (CO_2) ..	..	..	..	..	Nil	..	n.d.
Loss on ignition	0·20	0·65	2·20	1·55	0·35	0·88	2·82
Totals	100·27	100·30	100·13	100·40	100·32	100·15	100·34

	(8.)	(9.)	(10.)	(11.)	(12.)	(13.)	(14.)
Silica (SiO_2)	50·05	54·95	55·77	60·65	58·20	57·68	59·20
Alumina (Al_2O_3)	21·66	19·56	17·36	19·55	18·35	18·84	18·03
Ferric oxide (Fe_2O_3) ..	3·23	3·15	4·36	2·39	1·44	4·96	1·40
Ferrous oxide (FeO) ..	4·93	3·78	3·64	1·16	3·46	1·44	2·88
Manganous oxide (MnO) ..	0·06	0·08	0·07	0·08	0·35	0·21	0·40
Lime (CaO)	10·14	8·70	8·45	7·40	6·20	6·05	7·03
Magnesia (MgO)	3·51	3·01	2·73	1·16	3·49	4·00	2·51
Potash (K_2O)	1·59	1·59	2·27	1·98	2·96	2·15	2·28
Soda (Na_2O)	3·08	2·97	3·72	4·27	2·63	2·16	2·93
Titanium-dioxide (TiO_2) ..	0·95	0·80	0·74	0·35	0·87	0·82	1·26
Phosphoric anhydride (P_2O_5)	n.d.	n.d.	n.d.	n.d.	..	..	..
Carbonic anhydride (CO_2) ..	n.d.	n.d.	n.d.	n.d.	Nil	0·75	Nil
Loss on ignition	0·75	1·05	0·70	0·87	2·05	0·90	2·08
Totals	99·95	99·64	99·81	99·86	100·00	99·96	100·00

Localities of above analyses:—

(1.) Outcrop of boulders on Junction Road near Kent Road.
(2.) Quarry near Sentry Hill flour-mill.
(3.) Quarry near Moa Company's bore, Inglewood.
(4.) Quarry on Egmont Road, at bridge over Ngatoromarama Stream.
(5.) Quarry on Otaraoa Road.
(6.) Railway ballast-pit near Sentry Hill quarries.
(7.) Atuakake Creek, near Carrington Road.
(8.) Mangorei Creek, near southern boundary of the subdivision.
(9.) Smart Road—undecomposed igneous rock found occasionally in the "kaolin."
(10.) Waiwakaiho River, near its source on Mount Egmont.
(11.) Seaward face of Paritutu.
(12.) St. Paul's, Whangaroa, North Auckland.
(13.) Beeson's Island, Coromandel Peninsula, Auckland.
(14.) Coal Point, near North Cape.

The following analysis shows the composition of a rock from the Pouakai Range, which has apparently been altered by hydrothermal action :—

Silica (SiO_2)	46·77
Alumina (Al_2O_3)	18·29
Ferric oxide (Fe_2O_3)	1·10
Lime (CaO)	0·92
Magnesia (MgO)	0·70
Iron-disulphide (FeS_2)	7·93
Loss on ignition (excluding sulphur)	21·95
Alkalies and undetermined	2·34
	100·00

(2.) *Claystone Masses, Quartz Pebbles, &c.*—The distribution of the masses of claystone containing Miocene fossils and occurring in the agglomerates of the Pouakai Series has been sufficiently described under the heading of "Onairo Series" (p. 15). Small bands of water-worn pebbles of quartz, grauwacke, &c., are occasionally found, especially near the base of the series. In the gravel-pit near the gas-vent on Mr. Bishop's farm (see p. 44) fragments of baked and reddened claystone are occasionally found amongst the volcanic boulders, as already noted on p. 21.

(3.) *Lignitic Beds.*—The lignitic beds of the Pouakai Series occur most abundantly on the lower coastal plain between Bell Block and Urenui, where the great majority of household wells strike, at a depth of between 15 ft. and 30 ft., a layer of tree-trunks mixed with remains of smaller vegetation and with tufa and volcanic boulders, which continues for about 12 ft. to 20 ft. The same deposits, though not so strongly developed perhaps, occur in the high country inland fringing the Tapuae–Manganui Ridge. Proof of this is obtained in many of the road-cuttings and natural sections, and also in the various boreholes which have been put down in search of oil. Large deposits of similar material are said to have been encountered in the long tunnel driven in connection with the hydro-electric lighting scheme for New Plymouth. This tunnel cuts across the great bend of the Waiwakaiho River above its junction with the Mangorei Stream.

In the south-west corner of the Waitara Survey District lignitic deposits of a different type from those just described, but probably contemporaneous with the Pouakai rocks, are found over an area of about 96 acres, as indicated on the geological maps. These deposits consist of 12 ft. to 20 ft. of alternating layers of sand and impure peaty lignite. The sand is made up of fragmentary crystals of ferro-magnesian minerals and of very decomposed feldspars. In the upper layers the bands of sand are the thicker, whereas towards the base the lignite layers become predominant.

Mode of Origin.

The fragmental rocks of the Pouakai Series are, as already noted, almost entirely volcanic in origin. From the chemical and petrological characters of the rocks as detailed above it seems likely that the volcanic rocks originated mainly from the volcano or group of volcanoes which occupied the site of the Pouakai Range. From the water-worn character of the majority of the boulders, and the bedding exhibited, it would seem that the rocks were accumulated under water. It must be noted, however, that Dr. Wanner, of Bonn, who during his visit to the district in November of 1910 drew the writer's attention to the occurrence of baked claystone fragments near the Mangaone Stream (see p. 21), considers that there is evidence for the existence of a volcano in this neighbourhood in Pouakai times. Moreover, the coarse rudely bedded deposits of angular boulders which form the conical hills near Lepperton and Inglewood (see pp. 5, 21) are best explained as having originated from one or more vents

in the vicinity. The same is true of the boulders forming a knob on the south bank of the Waitara River, near the mouth of Mangaone Creek, and occurring in the quarry on the Otaraoa Road, about one mile north of the southern boundary of the subdivision.

As already noticed (p. 21), the lava-flows forming the prominent hill of Paritutu, near the New Plymouth Breakwater, are apparently overlain unconformably by a coarse volcanic breccia of the Pouakai Series. The exceedingly steep sides of Paritutu, which are due almost entirely to aerial erosion, are seemingly continued below the mantle formed by the breccia. This fact and the petrological differences between the lavas of the Sugar-loaves and the volcanic débris constituting the main part of the series under consideration (see above, pp. 22, 23) render it highly probable that some space of time separated the extrusion of these lava-flows from the deposition of the rest of the Pouakai rocks.

The apparent unconformity near Paritutu (referred to on p. 21) between the coarse breccia mentioned above and a fine volcanic sand is probably only local, since sand of the same character is seen conformably bedded with coarse breccia in the cliffs fronting New Plymouth and also near the western boundary of the subdivision.

It would seem, therefore, that the rocks of the Pouakai Series accumulated in rather an intermittent and spasmodic fashion (as might, indeed, be expected from their almost entirely volcanic origin), partly on land and partly in shallow water.

Age and Correlation.

The only fossils as yet found in the rocks of the Pouakai Series are the carbonized remains of plants, apparently identical with species at present growing in the district, but these do not afford any clear proof of age. Some evidence, however, as to the geological age of the rocks in question may be obtained from the relationship of the series to the preceding and succeeding ones.

Only two clear sections showing the relationship of the Pouakai and Onairo Series were seen—namely, on the sea-coast about three-quarters of a mile east of Trig. Station IX (Waihi), and on the Mangaone Road a short distance south of the southern boundary of the subdivision. In these places there seems to the writer to be decided unconformity between the two series. Again, at the swimming-baths near New Plymouth are found the erect carbonized stumps of trees, the roots of which ramify through the masses of claystone referred to above (p. 15) as possibly belonging to the Onairo Series. These trees are overlain by water-borne deposits of the Pouakai Series. If the claystones belong to the Onairo Series, and if they are *in situ*, an unconformity is clearly indicated in this locality.

On the sea-coast near the western boundary of the subdivision the remarkable occurrence of masses of claystone containing Miocene fossils has already been noted (pp. 15, 22). The large size of some of these masses makes it seem probable that they are *in situ*. If this be so, the concordance of bedding between these sedimentaries and the fragmental volcanic rocks of the Pouakai Series points to a conformity here between the two series. On the whole, however, the evidence seems to indicate that the Pouakai Series overlies the Onairo Series unconformably, though probably no great lapse of time is thus indicated. In this connection it is interesting to note that the volcanic breccias of the Manukau Heads, near Auckland, are generally considered to succeed the Miocene strata of the Waitemata beds conformably, and are similarly seen to do so at Parengarenga, near the North Cape.*

* Bell and Clarke: "A Geological Reconnaissance of Northernmost New Zealand." Trans., vol. xlii (1909), p. 619.

The rocks of the Pouakai Series are seen in many places to be unconformably succeeded by the Pleistocene and Recent deposits, to be described later.

As mentioned in the section on petrology, the volcanic rocks of the Pouakai Series show a strong resemblance to the andesitic agglomerates, breccias, flows, and dykes of remarkably constant chemical and petrological characters, which attain a wide distribution in the northern part of New Zealand, and to which a Miocene age is generally assigned.* Much detailed petrological and field work, especially along the coast-line between Mokau and the Manukau Harbour, must be carried out before the correctness of any correlation between the Pouakai Series and the supposed Miocene volcanic rocks of Northern Auckland becomes more than a probability. This correlation, if it be established, together with the evidences of a probably inconsiderable lapse of time between the deposition of the Pouakai and of the Onairo rocks, makes it reasonable to conclude that to the majority of the rocks of the former series should be assigned an Upper Miocene and Pliocene age. It should be noted that there is no evidence of any break separating the main part of the Pouakai Series from the latest accumulations due to the eruptions of Mount Egmont; also that the Kaitaki (Patua) Range is composed of volcanic rocks much more decomposed than the majority of the Pouakai rocks, and probably, therefore, either more or less contemporaneous with or older than the Sugar-loaf rocks.

It must be mentioned here that Marshall† considers the Pouakai rocks to be younger than the rhyolites of the Central Plateau, and therefore altogether distinct in age from the Miocene volcanics of Northern Auckland.

Pleistocene and Recent Rocks.

Introductory.

Pleistocene and Recent rocks are of widespread occurrence throughout the subdivision, but nowhere cover any very large area. The accumulations consist of gravels, sands, and muds, with very limited quantities of bog iron-ore. None of the deposits are more than very slightly consolidated. The materials under consideration may be divided into alluvial and swamp, marine and fluvio-marine, and æolian deposits.

Alluvial and Swamp Deposits.

The alluvial deposits consist mainly of silts, gravels, and sands of all degrees of coarseness.

The predominant alluvial deposits in the western portion of the subdivision are gravels and sands derived by erosion from the rocks of the Pouakai Series. These deposits are usually rather fine-grained, except in the actual watercourses, where large boulders may be seen. Silts formed from the claystones and sandstones of the Onairo Series are predominant in the valleys of the streams in the eastern portion of the subdivision. These silts always contain a small amount of ironsand derived from the volcanic rocks of the Pouakai Series, which, as already noted, form in many places a thin covering over the Onairo rocks. In the small tidal inlet at the mouth of the Mangaoraka Stream there are found near low-water mark a few beds of clay alternating with peaty matter. These beds are overlain by gravels containing pebbles up to 2 in. in diameter. The occurrence of this probably lacustrine deposit below sea-level points to a slight amount of depression in recent times.

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* Concerning these rocks see Bulletin No. 8 (New Series), N.Z.G.S., 1909, pp. 68–69, and literature cited therein.

† Aust. Ass. Adv. Sci., vol. x, p. 376.

Small swamps containing clayey deposits mingled with much carbonaceous matter are of wide occurrence throughout the subdivision, except near the headwaters of the streams which drain a land surface of Onairo rocks. In many places inconsiderable deposits of bog iron-ore have been formed in the small swamps, notably in the country near the upper (southern) part of Smart Road and Dorset Junction Road.

In a swamp near the head of the streamlet which flows north-west just north of Trig. Station D (Elliot), in Westown, a small deposit of infusorial earth occurs. The following is Dr. Maclaurin's report on a sample :—

"The sample was dried at 100° C. and analysed, with the following results :—

Silica (SiO_2)	73·61
Alumina (Al_2O_3)	12·85
Ferric oxide (Fe_2O_3)	0·14
Lime (CaO)	2·40
Magnesia (MgO)	1·10
Loss on ignition	9·90
	100·00

"The sample is mainly infusorial earth."

Of interest also are the peaty deposits which are exposed round the gas-vents in the upper waters of the Huatoki Stream, and which are also found in the upper waters of the Mangahewa and Puketotara streams, where they possibly mark the site of former gas-vents. The following is Dr. Maclaurin's report on three samples—(1) from Mangarewa Creek, (2) from Puketotara Creek, (3) from the neighbourhood of the gas-vents on Grooby's Farm (see Chapter III, p. 44) :—

"The samples were dried on a water-bath and analysed, when they proved to be peats of the following composition :—

	(1.)	(2.)	(3.)
Moisture	4·2	10·9	3·5
Organic matter	86·6	73·1	78·4
Ash	9·2	16·0	18·1
	100·0	100·0	100·0

"No infusoria were detected in the ash."

Marine and Fluvio-marine Deposits.

In the neighbourhood of the outcrops of coarse agglomerate, which occur chiefly along the western portion of the sea-coast of the subdivision, the beach deposits consist of rounded volcanic boulders of all sizes. With this exception, the marine and fluvio-marine deposits are formed almost exclusively of the well-known "Taranaki ironsands." These ironsands are black in colour, and apparently consist mainly of magnetite, ilmenite, and ferro-magnesian minerals derived from the decomposition of the rocks of the Pouakai Series. The fragmentary crystals of zincblende which are fairly frequent in the ironsand near the New Plymouth Breakwater are probably derived by denudation from the Kaitaki (Patua) Range, where this mineral is known to exist. Several other metals said to have been found in the ironsand in the neighbourhood of the Breakwater are probably derived from wrecks or such extraneous sources. The ironsands are further dealt with in Chapter III, p. 48.

Æolian Deposits.

The æolian deposits form the sandhills, the distribution of which has been sufficiently described in Chapter I, p. 6. These deposits consist almost entirely of "ironsand." In places the sand has been cemented by the deposition of iron-oxide, more especially where temporary swamps occur on the surface of the sand-dunes. On the Mokau Road, in the cuttings on the north bank of the Mimi Stream, loosely consolidated sands containing a considerable proportion of "ironsand" are seen. The same sands are found on the Tupari Road about three-quarters of a mile beyond its junction with the Okoke Road, and, unconformably overlying the Onairo rocks, on the sea-coast near the north-east boundary of the Waitara Survey District. These sands are apparently æolian in origin, and, since no sand-dunes at present exist precisely where they are found, should be classed as slightly older than the æolian deposits first mentioned.

CHAPTER III.

ECONOMIC GEOLOGY.

Introductory.

Regarded from the standpoint of economic geology, the New Plymouth Subdivision is interesting mainly in view of its possibilities as an oilfield, and to a minor extent on account of its large deposits of ironsand. This chapter, therefore, deals mainly with these subjects.

Petroleum.

Present Position of the Petroleum Industry in Taranaki.

At the date of writing (May, 1911) four oil-prospecting companies holding rights in or near the area under review are in existence. Of these, two (the Inglewood Company and the Taranaki Oil and Freehold Company) are not at present operating. The other two companies (the New Zealand Standard Oil and the Taranaki Petroleum Company) are engaged in boring. So far the Standard Oil Company of New Zealand has met with no pronounced success. The Taranaki Petroleum Company has two flowing wells yielding together about 110 barrels per week,* and has more than six thousand barrels of crude oil stored in underground tanks.

* A prospectus issued in April, 1912, gives the weekly yield from these two wells, and a third (No. 5), as 360 barrels.

HISTORY OF THE PETROLEUM INDUSTRY IN TARANAKI.

(1.) *Introductory.*

The presence of oil near the Sugar-loaves had been noted by the Maoris long before the arrival of Europeans, and was ascribed by them to the decomposition of the body of a sea-monster. According to one of their legends, Seal Rock, now a reef, was once an island of bituminous matter, which was ignited and then burned below the sea-level.

Dr. Dieffenbach* in 1839 noted the presence of oil near Moturoa, and also a "strong smell of sulphuretted hydrogen gas about a mile from high-water mark."

In 1865 the late Mr. E. M. Smith collected a sample of oil, which he forwarded to the Birmingham Chemical Association, which institution gave a "splendid report on the character of the oil."†

This account of the attempts to obtain oil in Taranaki is divided into two sections, the first dealing mainly with the first period of prospecting activity, between 1865 and 1868; the second with the renewal of interest in the venture between 1889 and the present day. In the second section the period of maximum activity and success (from about 1904 to the present day) is separated from the earlier period.

The sources from which this account has been compiled are very various. Special mention, however, should be made of the assistance received from a variety of documents lent by Mrs. Fair and Mr. F. P. Corkill.

(2.) *First Period of Activity:* 1865–68.

The first attempt to reach the supposed oil-reservoir was made at the end of 1865, when Messrs. J. F. Carter, Ross, J. R. Scott, and J. Smith obtained from the Provincial Government the right to bore or sink for oil on 50 acres of land near the Sugar-loaves. It was stipulated that a royalty of from 3 to 7 per cent., according to the depth, should be paid on any oil obtained. The first oil-well in the district, which was afterwards known as the Alpha or "Oil or London" Well (1),‡ was sunk as a shaft for a depth of about 60 ft. (which was reached on the 24th March, 1866), and continued by boring to a depth of about 180 ft. As will be seen by a study of the log contained on a separate sheet at the end of this report, "indications" were met with at various depths, the best being at 60 ft., where occurred a seepage of thick greenish-brown petroleum, and at 180 ft., at which depth, according to Hector, oil to the amount of about 50 gallons a week was skimmed off the water.

In order to develop these encouraging prospects a company known as the Taranaki Petroleum Company was formed about the end of 1866, with a capital of £10,000. This company also obtained from the Provincial Government boring-rights over an area of about 110 acres in the Sugar-loaf Reserve, immediately west of Carter and Company's lease; also over the islands of Pararaki and (subject to special conditions) of Mikotahi, and "over all that land lying between said reserve and low-water mark." It was stipulated that the company should spend at least £3,000 at a minimum rate of £1,000 per annum in sinking for petroleum before the works were abandoned.

The best yield obtained by the company from the Alpha Well was in July, 1867, when for a short period oil was pumped at the rate of 80 gallons a day. It is not clear, however, whether this oil came from the bottom of the well, or only from a depth of about 90 ft., from which level, when the well was plugged at a depth of 110 ft., oil was

* "Travels in New Zealand," vol. i, pp. 134, 135.

† These facts are from a letter from Mr. Smith to Mr. G. C. Fair, kindly lent to the writer by Mrs. Fair.

‡ These numbers are the index-numbers used to denote the wells on the geological maps. A list of Taranaki oil-wells arranged in chronological order forms an appendix to this report, and a tabular comparison of the records of most of the wells forms a separate sheet from which details as to the levels of oil-flows, &c., may be obtained.

obtained at the rate of 8 gallons per day. It does not appear that the Taranaki Petroleum Company deepened the Alpha Well after purchasing it.

About May or June, 1867, another bore, known as the Beta or "Oil or Edinburgh" Well (3), was begun by this company, from which, at a depth of 91 ft., 40 gallons of oil were obtained in ten or twelve hours. The yield, however, soon fell off to 3 or 4 gallons per day. Little else of interest, save the losing of the tools at 510 ft., and the abandonment of the bore at 684 ft., is recorded concerning this well.

The Taranaki Petroleum Company put down two other bores, known as No. 1 (4) and No. 2 (5), which reached depths of 310 ft. and 318 ft. respectively, apparently without encountering any hopeful indications. In addition to these bores, the company sank two shafts to depths of about 60 ft. each. In the latter part of 1868, discouraged by the failure of the Beta Well, the Taranaki Petroleum Company was voluntarily wound up.

While this company had been expending its capital on the sinking of four wells a smaller syndicate, known as the People's Petroleum Company, with a capital of about £3,000, began operations at the end of April, 1866, on an area of about 4 acres immediately east of Carter's claim, one of the conditions of the lease being that the company should spend at least £1,000 at the rate of £500 per annum in sinking for petroleum before the works were abandoned. A well, known as the Victoria or "Oil or Dublin" (2), was sunk to a depth of 516 ft. with apparently no tangible results. This practically ended the operations of the People's Petroleum Company, which amalgamated with the Taranaki Petroleum Company, and with it was wound up towards the end of 1868.

In June, 1866, Mr. (afterwards Sir Julius) Vogel began, it is said, to put down as a private venture a bore on ground adjoining Carter's lease. At 17 ft. encouraging indications of gas and oil are reported to have been encountered, but no authentic account of these operations could be obtained by the writer.

It is said that about the year 1880 two Germans put down a couple of bores "near the Manganui River," but no further information regarding this venture is obtainable.

(3.) *Second Period of Activity:* 1889 *to the Present Day.*

(*a.*) 1889–1904.

The second period of activity began in 1889, when, owing to the exertions of Mr. Oliver Samuel and Sir Julius Vogel, a company called the New Zealand Petroleum and Iron Syndicate (Limited) was formed in England. Plant was sent out from England, and an American driller (Booth) was engaged. Mr. Charles Marvin, the well-known English oil expert, who had been appointed managing director, and was to have proceeded to New Plymouth to select the site of the bore and superintend drilling operations, died when just about to leave for New Zealand. The loss of his advice no doubt had much to do with the half-hearted support which the enterprise received from the English directors. Messrs. F. P. Corkill and O. Samuel were appointed local directors, Mr. Corkill acting as general manager and attorney for the company in New Zealand.

A site was selected at the base of the Breakwater (6), and drilling was begun by Booth on the 8th January, 1891. Boring appears to have proceeded with expedition, and at a depth of about 915 ft. oil was obtained at the rate of about four barrels a day. Shortly after this the tools were lost in the bore, and many fruitless attempts were made to recover them, great inconvenience being caused by the lack of monetary support accorded by the board of directors in England. Finally operations were abandoned owing to the want of funds, although the enterprise appeared to be on the threshold of success, and the driller (Booth) claimed to be able to pump 160 gallons of oil a day, and strongly recommended deepening the well by another 200 ft. On the 10th May, 1894,

the property of the Petroleum and Iron Syndicate was sold in order to pay outstanding debts, and the plant was acquired by a syndicate of Taranaki and Sydney residents, referred to in this report as the Samuel Syndicate, by which a most determined effort to find payable supplies of oil was made.

The services of a driller named Ludlow having been obtained, an attempt was made to reopen Booth's well (6), which, from the quantity and variety of iron implements which it contained, would appear to have been intentionally blocked by some individual. Following this failure, R. E. Fair and two other drillers from Australia were employed to sink another well (7), about 8 ft. west of Booth's. After a number of mishaps, due to losing tools, &c., the hole was sunk to about 950 ft., when oil to the amount of two or three barrels a day was obtained. At 1,000 ft. a flow of about ten barrels a day was obtained. Much excitement was caused locally by this success, and many applications for shares were received, but Mr. Samuel, recognizing that the results had been greatly exaggerated, obtained the subscription of further capital privately, so that the general public should not suffer in the event of failure. During this period of success the first consignment of crude petroleum from Taranaki was shipped to the Balclutha Water-gas Company, which continued for some time to be a regular customer. The Railway Department also for some years purchased crude petroleum for the manufacture of gas at its Petone works. Ultimately, owing to difficulties with the water which could not be overcome, No. 2 (7) was abandoned when at a depth of 1,100 ft. (or perhaps only 1,021 ft.). It should be added that this well was cased to a depth of 885 ft., and, as in No. 1 (6), the water was found to rise and fall with the tides.

No. 3 (8), or Mace's, or the Herekawe bore, was then put down on Mr. Mace's farm on the Herekawe Stream, close to the New Plymouth – Omata Road, and was abandoned on the 26th October, 1895, after a depth of 1,534 ft. had been reached. Little oil was seen, but large quantities of gas were met with, and it is asserted that oil was seen flowing from the well after its abandonment. It is noted that in one part of the well sinking was much facilitated by the striking of a seam of quicksand, through which the casing sank by its own weight, so that the bore was sunk through this stratum at the rate of 10 ft. or 12 ft. in thirty minutes.

No. 4 (9), or Samuel's bore (the No. 3 well of the present Taranaki Petroleum Company), was begun on the 11th November, 1895. At 908 ft. a large escape of gas was encountered, and at 910 ft. oil at the rate of ten barrels a day was obtained. Considerable difficulty was experienced in working the pump, which was frequently blocked by the mixture of fine mud and oil. Shortly after this the flow suddenly ceased, most probably owing to the caving-in of the claystone which overlay the emptied oil-seam. Boring was therefore resumed, and "shows" of oil were encountered at various levels down to 1,976 ft. At this depth oil at the rate of eight barrels a day was for a short time obtained by pumping. Unfortunately, on the 22nd August, 1896, a fire, caused by the accidental ignition of the escaping gas, destroyed the derrick and plant. Undaunted by this mishap, Mr. Samuel, who had assumed the direction of operations after the departure of Mr. Fair on the 29th February, 1896, proceeded immediately with the erection of new plant. This work was completed by October, 1896, and the water at 1,885 ft. having been shut off and a packer placed at 1,934 ft., oil unmixed with water began to flow at the rate of 270 gallons per twenty-four hours. After a great many accidents to tools, casing, &c., the bore, in spite of the considerable quantity of oil which had been obtained from it, was finally closed down.

The narrative of the Samuel Syndicate's doings may here be interrupted to note that in August, 1896, was issued the prospectus of the Egmont Petroleum and Mineral Boring Company (Limited), which held rights over an area extending from Barrett Road, across the Frankley, Carrington, and Mangorei Roads, and over another area in the Inglewood

district. The total area over which boring-rights were obtained by this concern was about 5,000 acres. Owing, however, to the partial failure of the boring operations of the Samuel Syndicate, there was but small demand for shares, and the Egmont Petroleum Company failed to materialize—a matter to be regretted, as in the writer's opinion the ground formerly held by this company deserves closer examination than it has yet received. It may also be mentioned here that Mr. P. McColl, of Omata, is said to have drilled one or two holes to some depth with a very primitive apparatus about the year 1896. The approximate situation of these works, no results of which are available, is shown on the map (10).

No. 5 (11), or Putt's bore, together with all the wells put down thereafter by the Samuel Syndicate, was sunk under Mr. Samuel's direction. It was situated about 100 yards south-west of No. 4, and reached a depth of 2,053 ft. during the early part of 1898, but, though several oil-bearing seams were cut, at no level could more than one barrel of oil per day be obtained.

No. 6 (12), or Okey's bore, situated about four miles south of the Breakwater, was abandoned at a depth of 302 ft. owing to the great difficulty experienced in drilling through a coarse volcanic material. Often for days together not an inch of progress was made with the drilling.

No. 7 (13), or Veale's bore, was situated near Okey's bore. Boring was begun in August, 1898, and reached a depth of 1,220 ft. On the 21st February, 1899, the company, the Australian members of which had apparently become discouraged by the repeated failures to obtain oil, sold its rights and plant to Mr. L. W. Alexander, of New Plymouth. He in turn sold to a small syndicate of New Plymouth residents, of whom Mr. Samuel was the principal shareholder. Under his superintendence No. 7 (13) bore was sunk by the new company to a depth of 1,335 ft. without any encouraging prospects, and was then abandoned.

Undeterred by these repeated failures, Mr. Samuel then began No. 8 (14) bore. This bore was situated a few hundred yards south of No. 4 (9), which was still intermittently producing oil. As may be seen by a glance at the log of this bore, encouraging indications were met with, the explosion of gas and oil marked as occurring at 1,730 ft. being sufficiently powerful to throw water and mud to the top of the derrick. Below 1,730 ft., however, no traces of oil were encountered, and when a depth of 2,052 ft. had been reached the casing was drawn and the bore abandoned.

No. 9 (15) bore was situated close to No. 4 (9). Drilling was begun on the 10th December, 1900, and when the well had reached a depth of 1,080 ft. without result it was abandoned.

This ended the activity of the Samuel Syndicates. With the exception of No. 4 bore, their persistent efforts did not meet with success. The only positive conclusion to be drawn from the operations just detailed is that the main supply of oil is situated at a considerable depth, and that bores which do not attain a depth of at least 2,000 ft. below sea-level are of little value.

(*b.*) 1904 to the Present Day.

During this period the prospects of the oil industry in Taranaki have become much brighter, and as a consequence several companies have been formed. In this section the doings of each company are separately outlined.

(i.) *The Moturoa and Taranaki Petroleum Companies.*—In 1904 operations took a fresh lease of life, when the rights and machinery of the company which put down the bores Nos. 8 (14) and 9 (15) were sold to a syndicate largely financed in Adelaide. The late Mr. G. C. Fair was engaged as head driller, and on the 27th April, 1904, he began drilling the Birthday Well (16) a few hundred yards south of No. 4 (9). By January, 1905, the well had reached a depth of 2,100 ft. at a cost of £1,800, without, so far as can be now ascertained, having encountered any very promising indications. At this stage

the Adelaide syndicate, being unable to find further capital, sold the plant and rights to a small company called the Moturoa Petroleum Company. This company had a capital of £2,000, and was formed in New Plymouth, chiefly through the exertions of Mr. G. C. Fair, who was very sanguine of the ultimate success of the project. With the aid of a Government subsidy of £1 per foot for 230 ft., the Moturoa Petroleum Company increased the depth of the Birthday Well to 2,230 ft., when, on the 22nd June, 1905, good oil was obtained, and the success of the company seemed assured. Difficulty, however, was experienced with the water, and it was decided to recase the well. This was a very difficult matter, because (owing to want of money) the original casing used was very defective. In order to obtain more capital the Moturoa Petroleum Company was merged into the present Taranaki Petroleum Company. This company has a capital of £120,000, of which £56,000 in fully-paid-up shares was allotted to the shareholders of the Moturoa Petroleum Company, and of the balance between 31,000 and 32,000 shares have been issued, on which 17s. 6d. per share has been paid up. By the 26th April, 1906, the bore was recased and the water supposed to be shut off. The casing, however, is in a very bad state, being much bent, and having one or two holes punched right through it. The depth of the well was increased to 2,345 ft., and good oil was obtained from it. Eventually, owing to renewed difficulty with the water, the well was abandoned.

In 1907 the company proceeded to clean out the bore, and during the year got down to a depth of 2,269 ft. Throughout 1908 and 1909 this work was temporarily abandoned, but in 1910 fresh efforts were made to clean out the well and insert 6 in. casing. This work was carried out to a depth of 2,320 ft. Operations have ceased at this bore for a time. It appears likely that in the same time and for the same money a fresh bore might have been put down alongside to a greater depth.

In August, 1906, Mr. Fair began putting down the No. 2 (17), or Roy's well, situated between (16) and (9), but unfortunately died before any great progress had been made. The sinking of the No. 2 well was continued under the managership of Mr. W. A. Simpson, who was succeeded by Mr. L. Keith at the end of 1909, and under his direction the operations of the company are now proceeding. In the No. 2 (17) oil and gas were met with in small quantities at various depths, as much as two barrels of oil per day being obtained from one seam at a depth of 1,872 ft. During 1909 Mr. Berry, a former director and chairman of directors, urged that sinking should be continued, and, this having been done, at a depth of 2,209 ft. a considerable quantity of oil and very salt water was obtained. It is said that during a period of thirty-one days thirty-seven barrels of oil per day were obtained, but subsequently the yield decreased. Mr. Berry, who expressed himself as dissatisfied with the methods of management, undertook, subject to a penalty of £2 per day for failure, to obtain oil from the well at the rate of twenty barrels per day for twenty-four days. Mr. Berry did not succeed in fulfilling his engagement, but nevertheless effected many improvements in the state of the well, and during an actual pumping-time of twelve days obtained 144 barrels of oil. Drilling was continued at this well until, at a depth of 3,030 ft., on the 5th January, 1910, a flow of oil at the rate of about ten barrels per day began and has continued steadily ever since. According to local report, No. 2 bore is not in a very satisfactory state, 250 ft. of casing being, it is asserted, adrift somewhere in the well. This bore, nevertheless, has so far been the most successful in the district.

Simultaneously with the drilling of No. 2 (17), the company began operations at two other wells, known as the No. 3 (9) and the No. 4 (18). The No. 4 (9) well of the Samuel Syndicate, being the third well to be worked on by the present company, is now known as the No. 3. Very great difficulty and expense were incurred in trying to clean and deepen this well, but ultimately success was attained. Boring has continued at intervals ever since, the most serious mishap being the burning-down of the derrick on the 6th or 7th September, 1909. No. 3 well has now (May, 1911) a depth of 3,841 ft., being more than 800 ft.

further below sea-level than any other well in the district, and has produced since the 2nd March, 1910, oil at the rate of about eight barrels per day.* The progress of boring does not interfere with the escape of this oil, which comes to the surface between the 4 in. casing and the 5 in. casing, probably from depths of 2,800 ft. and 3,088 ft. Between 3,710 ft. and 3,720 ft. great gas-pressure was encountered, blowing water and oil to a height of 70 ft. above the derrick, and necessitating the cessation of work for some days.

No. 4 (18) well of the Taranaki Petroleum Company was drilled simultaneously with the operations detailed above. It was situated a little south of No. 1 (16), reached a depth of 1,678 ft., and then, owing to difficulties with quicksand, was closed down, no decided indications of oil having been met with.

No. 5 (25) bore, which is situated close to No. 1, but on the seaward side of the railway-line, was apparently put down mainly with the object of retaining the rights over the ground on which it stands. Drilling appears to have gone on satisfactorily at this well, which is now (May, 1911) 1,745 ft. deep, and according to a Press message at the beginning of April of this year "two exceptionally violent blow-outs" at depths of 1,010 ft. and 1,535 ft. occurred. "The boring-tools were hurled out of the casing with terrific force, wrecking 200 ft. of steel cable. The débris was scattered for a quarter of a mile around, despite the fact that the derrick was roofed in."†

Before concluding the account of the operations of the Taranaki Petroleum Company it may be noted that latterly the gas, which escapes in great quantity from bores 2 and 3, together with some waste oil, has been used almost exclusively for firing purposes, a considerable saving in working-expenses being thus effected.

For the purpose of bringing the potentialities of the industry before the public, a miniature refinery was erected at the works in 1910, and some hundreds of samples of the various products were distributed in and beyond the Dominion.

With a view to attracting the attention of the Admiralty, which had decided to adopt the use of liquid fuel in the navy, twenty-five barrels of crude oil during 1910 were presented to the authorities for test purposes. At the time of writing the results are not to hand.

During 1910 also a hundred barrels of crude oil were purchased by the New Zealand Government for the purpose of testing the comparative merits of oil and coal as steam-producers on the railways. It is understood the results were satisfactory.

Since writing the above it has been announced that as the result of a visit of inspection by Mr. J. D. Henry, editor of the *Petroleum World*, the sale of the Taranaki Petroleum Company's property to a powerful British syndicate has been arranged.

(ii.) *The Inglewood Oil-boring and Prospecting Company (Limited)* was promoted in 1906 by a number of New Plymouth and Inglewood residents. The capital of the company was £10,000, in £10 shares, which were afterwards divided into £2 shares. Of this capital £6,655 was called up. The plant, which, with the derrick, cost £2,800, was purchased by the driller, Mr. A. D. McDonald, from the Oil Wells Supply Company in Pittsburg, and drilling was begun on the 9th September, 1907, on a site (23) close to the railway-line and about three miles south of Inglewood. Drilling appears to have proceeded successfully, except that the water was never properly shut off. On the 13th August, 1908, Mr. McDonald advised that, since the bore had reached a depth of 2,500 ft. without any decided indications of oil, further boring was not warranted and the well should be abandoned. Drilling therefore ceased after an expenditure of about £6,780; but the greater part of the plant remains at the bore, and the company still holds boring-rights over 1,300 acres in the neighbourhood, and over a considerable area near the Mokau River. Negotiations concerning these rights are at present proceeding with

* In February, 1912, the production of this well was reported as forty barrels per week.

† Towards the end of February, 1912, this well, at a depth of 2,323 feet, struck a flow ofoil estimated for the first day at 7·5 barrels. In April the flow had lessened considerably, but was still satisfactory.

English capitalists. Considering the depth at which good results had been obtained at Moturoa, the company might well have deepened the borehole by another 1,000 ft. before stopping active operations.

(iii.) *The Moa Petroleum (Limited).*—A company known as the Moa Petroleum (Limited), the promoters of which appear to have been Wellington residents, began drilling operations close to the town of Inglewood (22) in August, 1907. The total number of shares issued by the company was 6,500, of which 1,500 were allotted as fully paid up. The total cash received by the company in respect of the contributing shares was £997 10s. The head driller was Mr. A. D. McDonald, who was also directing operations at the Inglewood Petroleum Company's bore, and was especially sent to Pittsburg by the two companies to obtain their plant. Apparently owing to lack of funds, the well was abandoned in January, 1908, when at a depth of about 460 ft. Two sets of boring-tools are reported to have been left at the bottom of this well. Promising indications are said to have been met with when the hole was between 200 ft. and 300 ft. deep, but, having regard to the experience of all other wells in the district, there is no doubt that much greater depths would have to be reached before any reliable information as to the value of the property could be obtained. At present the derrick, machinery, and tools are still in position.

(iv.) *The New Zealand Standard Oil Company (Limited)*, mostly financed, as the writer understands, by Auckland capital, began boring operations in December, 1907, on a site (24) near the Carrington Road close to the southern boundary of the subdivision, about five miles south of New Plymouth and within half-mile of the gas-vents on the Huatoki River (see p. 43). Drilling has continued with fair regularity since, and the depth of the bore was stated to be somewhat over 3,200 ft. in the early part of 1911. The company has a well equipped and maintained boring plant, and during 1910 constructed a large concrete-lined reservoir for the reception of the expected oil. So far, however, nothing very tangible has been obtained. Recently the company has gone into voluntary liquidation, but it is understood that reconstruction is probable.

(v.) *The Taranaki Oil and Freehold Company (Limited).*—This company was formed towards the end of 1906 for the purpose of purchasing and exploring for petroleum a 10-acre block of freehold land in Vogeltown, one of the suburbs of New Plymouth. The capital was fixed at £15,000, in £1 shares, of which 13,500 have been allotted. The direction of the drilling operations was put in the hands of Mr. W. Balloch, who had had long experience in well-boring, including a period spent in the oilfields of South Russia. Drilling was begun in June, 1907, and continued for over two years, progress being slower than had been anticipated, owing, it is said, to the difficult nature of the country encountered, to the large diameter of the bore, and to various mishaps. The first signs of oil were met with at 450 ft., and "shows" were got at various depths down to 975 ft., where a so-called petroliferous sand was met with which is reported to have yielded oil at the rate of four barrels per twenty-four hours. Indications from this point downwards continued, it is said, to be most encouraging, more especially between 1,160 ft. and 1,200 ft. At 1,385 ft. boring was discontinued for want of funds, and, although the directors are confident that capital enough could be raised locally to continue operations for a time, they are, the writer has been given to understand, endeavouring to secure the interest of large capitalists. The works have been standing idle since about December, 1909, but are kept in good order.

(vi.) *The Bonithon Freehold Petroleum Company (Limited)* was registered on the 25th July, 1905, with a nominal capital of £25,000, in £5 shares, for the purpose of obtaining an oil-boring plant, and purchasing and exploring for oil a freehold property known as "Bonithon," situated between New Plymouth and the Breakwater. There was never, apparently, a very keen demand for shares in the company, and a large amount of the

money received in the form of calls had to be credited to the vendors in reduction of their claim of £5,250 for the balance of the purchase-money. A bore was sunk by contract to a depth of 3,000 ft., and, though encouraging indications are said to have been obtained, oil in any quantity was not met with. At length, on the 1st December, 1908, the available capital being exhausted, it was resolved to wind up the company.

At present, the writer understands, there is a proposal afoot to form a company, to be known as the Bonithon Freehold Petroleum Extended Company (Limited), to take over the assets of the former company and to sink the present bore an additional 500 ft. or until oil is struck. These proposals are embodied in a glowing prospectus, the authorship of which appears to be a secret.

(vii.) *The New Plymouth Petroleum Company (Limited)* was formed early in 1907 with a capital of £10,000, in 2,000 £5 shares, of which 100 shares in addition to a sum of £2,500 were allotted to the vendors for their boring options. 1,500 fully-paid-up shares, the majority of which were taken up in Dunedin, the headquarters of the company, were offered to the public. Drilling under the direction of Mr. H. E. Bunger, from California, was begun near Omata (19) in March, 1907, and ceased in November of the same year owing to lack of funds, when the bore had reached a depth of 1,060 ft. The abandonment of this bore at such an inconclusive depth is much to be regretted. Quite apart from the fact that the tools are said to have frequently come up dripping with oil at the 1,060 ft. level, the neighbourhood of this bore is one which in the writer's opinion deserves thorough prospecting by means of holes of an adequate depth.

(4.) *Comments on Prospecting Methods.*

The importance and extent of the Taranaki oilfield still remain to be proved. Considering the time and money which have been spent in oil-prospecting in the district, the amount of evidence for or against the existence, in the area under discussion, of the large oilfield in which so many people firmly believe is small. The following are the most obvious reasons for this disappointing result:—

(*a.*) The crowding of bores in the neighbourhood of the Breakwater. This crowding policy, which would be understandable in an established oilfield, seems inexplicable in the case of avowed prospecting companies.

(*b.*) The abandonment of bores at insufficient depths.

(*c.*) The total absence in some cases, and the fragmentary character in most others, of records of the strata passed through in the bores.

(*d.*) The total absence in most cases, and the fragmentary character in almost every other, of samples of the strata passed through in the bores.

(*e.*) Inaccuracy in recording depths from which samples are obtained. Many cases have come under the writer's notice of samples being definitely labelled as coming from a certain depth when from a comparison with neighbouring bores it is certain that the rocks in question had fallen in from above.

(*f.*) In the case of logs unaccompanied by actual samples, the great inaccuracy and inadequacy of the descriptive terms employed.

(*g.*) Generally the absence of the most modern methods, and of expert advice and supervision. Companies now operating have made some improvement in these matters, but much yet remains to be done.

THEORIES REGARDING THE ORIGIN AND MODE OF ACCUMULATION OF PETROLEUM.

(1.) *Origin.*

Theories regarding the origin of petroleum, natural gas, and allied substances may be divided into two classes. According to the "inorganic theory," oil and gas were formed

by water coming in contact at great depths with highly heated carbides of iron, manganese, and other metals. Upholders of the "organic theory" maintain that the vast majority, if not all, of the petrolaceous products have been formed by the alteration of organic remains entombed in sedimentary rocks. As to whether this alteration is due to slow distillation combined with bacterial action taking place at low temperatures, or to distillation at higher temperatures due either to the deep burying of the remains in question or to the action of intruded igneous rocks, there is not as yet universal agreement among the upholders of the "organic theory."

The evidence favouring the "organic theory" is almost overwhelming, and recent investigations indicate that slow distillation at low temperatures is the more probable of the two views as to the means by which the organic matter was altered.

(2.) *Mode of Accumulation.*

The most widely accepted explanation of the mode of accumulation of petroleum is that known as the "anticlinal theory." Petroliferous strata commonly consist of more or less rapidly alternating beds of sand and clay. It is generally believed that the petrolaceous substances were originally formed in the shales, and afterwards slowly made their way into the overlying more sandy layers, from which their escape directly upward was prevented by overlying beds of more clayey material. The petrolaceous products, being of less specific gravity than the water contained in the strata, would tend to flow upwards along the undersurface of the impervious clay beds, and would thus tend to accumulate along the crests of anticlines. According to this theory, then, the most favourable sites for bores are along the anticlines of the petroliferous series. The anticlinal theory of oil-accumulation has been very largely corroborated by actual experience in many petroliferous districts.

EVIDENCE AS TO THE EXISTENCE OF PAYABLE OIL-RESERVOIRS IN OR NEAR THE SUBDIVISION.

(1.) *Recapitulation of Geological Structure of the Subdivision.*

As the reader will have observed from statements on former pages (see especially pp. 12, 16, and 25) the petroliferous strata of the New Plymouth Subdivision—*i.e.*, the Onairo Series—are overlain by the accumulations of volcanic débris called in this report the Pouakai Series. As a rule, the Pouakai Series is unconformable to the Onairo Series, but it seems probable that no great lapse of time separates the two series, and that in some places they are actually conformable. If this be the case, the inclination of the Pouakai beds should form a key to that of the Onairo Series when the latter cannot itself be seen. The Pouakai beds, however, are nearly always horizontal. Either, therefore, the petroliferous Onairo Series is horizontally bedded in the western portion of the subdivision, or no clue as to its arrangement is obtainable. In the more eastern portion of the subdivision it has been shown that there is some evidence that the Onairo rocks form the western end of an easterly-pitching anticlinorium, the axis of the anticlinorium running in an east-south-east direction through the southern portion of the Waitara Survey District. The unconformities, in the Onairo Series itself, recorded by previous observers, would possibly be planes along which the ascending petroliferous substances would make their way to the surface. The writer, however, has been unable to find any evidence of such unconformities. The conclusion arrived at, therefore, is that the geological structure of the subdivision, so far as it has been possible to decipher it, affords no indication as to the distribution of oil-reservoirs.

It is possible, however, that the distribution of oil-seepages and gas-escapes may offer some clue as to the position of petroleum-reservoirs. It is proposed, therefore, to state on the following pages what is known as to the distribution of surface indications in and near the subdivision.

(2.) *Oil-seepages.*

The only undoubted occurrences of petroleum at the surface within the subdivision are the seepages which occur on the sea-bottom near the Breakwater at New Plymouth. On calm days the sea is often covered for a considerable distance with a film of oil. At the present time the dredge at work inside the Breakwater brings up a sufficient quantity of oil mixed with the débris to preserve the machinery from rust. A large number of reported oil-seepages were examined by the writer, but the great majority proved to be merely scums of iron-oxide formed by the oxidation of ferrous carbonate. In other cases this scum was found to be organic in origin, and due either to abundant fresh-water algæ, or to the decomposition of animal or vegetable matter.

The following reported oil-seepages deserve more detailed description :—

(1.) In the creek about half a mile south of Trig. Station D (Elliot), in Westown, near New Plymouth, oil is said to have been seen floating on the water. Nothing of any moment was observed on the occasion of the writer's visit.

(2.) About 20 chains east of the mouth of Waireka Creek a decided smell of oil* was noticed by the writer whenever he visited the place. There is probably an oil-seepage amongst the coarse boulders which lie along the base of the low cliff.

(3.) On the Sugar-loaf Motumahanga a smell of oil was noted by the writer in February, 1910.

(4.) During the summer of 1910–11 an escape of oil (and of gas) in the Waiwakaiho River, between the railway and traffic bridges, was reported in the local papers. The writer visited the locality several times, but was unable to detect any trace of oil, although the exact locality was indicated by the discoverer, Mr. A. E. Watkins.

(5.) In April, 1911, according to Press Association telegrams, "splendid indications" of oil were found in freshly dug post-holes on Mr. Henry Weston's farm on Frankley Road. The writer understands, however, that the report was exaggerated.

(6.) In a letter to the writer in April, 1911, Mr. R. W. Davies, of Westown, mentioned finding, when working at a depth of about 5 ft. in a new drain, a good "show of oil" about 8 chains from the New Plymouth Oil and Freehold Company's bore. The writer has had no opportunity of visiting either of the last two seepages.

(7.) In early days, before the existence of any commercial undertakings which might have given rise to the phenomenon, large patches of oil are said to have frequently been noticed floating on the sea at the mouth of the Waitara River. It is possible that the oil had drifted from the Sugar-loaves near New Plymouth, where, as mentioned above, films of petroleum are still frequently seen extending over considerable areas.

(8.) Near the junction of the Devon and Richmond Roads, just west of Waitara, oil is said to have been seen oozing out of a bank and flowing into a small stream. Many other oil-seepages are reported from this neighbourhood. All seen by the writer were scums of iron-oxide.

(9.) Thirty-five years ago strong traces of oil are said to have been found by Messrs. Vickery and Hicks when digging a sheep-dip near the old military settlement of Tikorangi. Almost the exact location of the sheep-dip was indicated to the writer by Mr. Hicks, and two holes were dug to what he considered the depth at which the oil had oozed out in former days, but no trace of petroleum was observed.

(10.) Close to the farmhouse at the junction of the Kelly and Ackworth Roads petroleum is said to be found as a scum on the surface of the water of a small spring, especially after heavy rains. The owner of the property asserted that this scum had more than once been

* It should be noted that in this and the following case where the smell of oil is noted the direction of the wind precluded the possibility of the smell having come from the Taranaki Petroleum Company's bores at Moturoa.

collected and burnt by means of a small wick. Samples of the scum taken by the writer contained nothing but iron-oxide.

(11.) At Inglewood, between the Moa bore (22) and the Mountain Road, which runs alongside the railway-line, there are numerous occurrences of iridescent scum in a piece of swampy ground, and a smell of petroleum has also been occasionally detected. A sample of the scum, however, was found by the Dominion Analyst to contain no petroleum. A similar scum seen on the same property near the Wortley Road proved to be iron-oxide.

(12.) On the Bristol Road, near its junction with Junction Road, a good show of oil is said to have been seen during the summer of 1909–10. When examined by the writer in the summer of 1910–11 the scum was evidently iron-oxide.

(13.) Seepages of oil are said to occur near the Manganui Stream, on the southern boundary of the subdivision at the junction of Bristol and Everett Roads, and again on the left bank of the Manganui Stream. These seepages appear to be merely iron-oxide.

(14.) A great number of wells in various parts of the subdivision are said to yield water with a flavour of kerosene. So far as the writer had an opportunity of judging, the unpleasant taste is due to excess either of iron-oxide or of organic acids in the water.

(15.) Just south of the southern boundary of the subdivision, on a farm on the north side of Kent Road, about half a mile beyond the junction of Kent and Junction Roads, during the summer of 1907 a sample was obtained which was analysed by a druggist in New Plymouth and found to contain oil. At present the very smallest traces of what is possibly oil are occasionally found, but on the occasion of the writer's visits the quantity was too small for any conclusive tests.

(3.) *Analyses of Oil.*

The crude petroleum which is at present being obtained from the Taranaki Petroleum Company's No. 2 and No. 3 bores (17 and 9) is at ordinary temperatures a thick viscous fluid, green by reflected and reddish-brown by transmitted light. The oil is mixed with saline water. Water from No. 2 bore, after separation from the oil by settling, was collected during the summer of 1909–10, and yielded the following analysis (results expressed in parts per 100,000) :—

Sodium-iodide	2·0
Potassium-chloride	193·7
Sodium-chloride	3113·6
Calcium-chloride	439·8
Magnesium-chloride	453·6
Aluminium-sulphate	3·8
Sodium-silicate	4·5
Calcium-bicarbonate	254·8
Ferrous bicarbonate	4·2
	4470·0

Dr. Maclaurin remarks, "This is a muriated saline water containing about 25 per cent. more salts than ordinary sea-water. It differs from sea-water mainly in containing very much more calcium-bicarbonate and practically no sulphates. It contains a considerable amount of iodine, and in general composition resembles some of the Kreuznach (Rhenish Prussia) brine springs, which are reputed to have considerable medicinal value."

The oil, after separation from the water, usually solidifies at about 69° Fahr., but the melting-point varies somewhat. The specific gravity is given by Pond as 0·832 at 80° Fahr., by Easterfield as 0·84 at 65° Fahr., by Skey as 0·8275 at 60° Fahr. According to an anonymous writer,* the crude oil ignites at 260° Fahr., and boils at 340° Fahr. Skey states that the flashing-point and boiling-point are 106° and 230° Fahr. respectively.

The following are analyses of Taranaki oil from various localities, together with an analysis of oil from Waitangi Hill (Gisborne) and one of oil from Kotuku (Westland) :—

* *Mining Journal*, 18th June, 1910.

	(1.)		(2.)		(3.)		(4.)		(5.)		(6.)		(7.)		(8.)		(9.)	
	Per Cent.	Specific Gravity.	Per Cent.	Specific Gravity.	Per Cent.	Specific Gravity at 15·5° C.	Per Cent.	Specific Gravity at 15·5° C.	Per Cent.	Specific Gravity.	Per Cent.	Specific Gravity.	Per Cent.	Specific Gravity.	Per Cent.	Specific Gravity.	Per Cent.	Specific Gravity.
Water	..	..	1·4	..	0·15	..	..	..	Nil	..	2·7	..	9·5	..	0·2	..	Nil	..
Benzene distilling below 150° C.	20·0	0·764	15·0	0·799	0·85	..	5·6	0·7654	20·2	0·7601	14·0	0·7426	5·0	..	0·5	..	4·1	0·7594
Burning-oil distilling between 150° and 300° C.	40·0	*0·82	42·0	0·841	30·0	0·8070	37·2	0·8053	42·8	0·8351	39·0	0·8317	20·0	..	39·0	0·8344	42·4	0·8443
Lubricating-oil distilling between 300° C. and 440° C.	24·0	..	20·3	..	48·0	..	35·2	..	22·1	..	20·5	..	59·0	..	60·3	0·9002	47·8	0·9024
Paraffin	13·0	..	13·3	..	21·0	..	22·0	..	10·3	..	14·5	..	Nil	..				
Pitch or coke	2·0	..	5·0	..	..	..	..	..	4·6	..	5·3	..	4·0	..	..	..	5·2	..
Loss	1·0	..	3·0	..	..	..	..	..	..	..	4·0	..	2·5	..	..	..	0·5	..
Totals	100·0	..	100·0	..	100·0	..	100·0	..	100·0	..	100·0	..	100·0	..	100·0	..	100·0	..

* For that distilling between 150° and 270° C.

Localities.

(1.) From No. 1 well, Taranaki Petroleum Company. (Analysis by Professor Easterfield, June, 1906.)

(2.) From No. 1 well, Taranaki Petroleum Company. (Analysis by Colonial Analyst, July, 1905.)

(3.) From No. 2 well, Taranaki Petroleum Company. (Analysis by Dominion Analyst, April, 1910. Sample collected by the writer.)

(4.) From No. 3 well, Taranaki Petroleum Company. (Analysis by Dominion Analyst, April, 1910. Sample collected by the writer.)

(5.) (Probably) from last well sunk by Messrs. O. Samuel and Co. near the Breakwater. (Sample forwarded by Mr. E. M. Smith in October, 1903. Col. Lab. Rep. 1904, p. 24.)

(6.) From New Plymouth (exact locality not stated). (Forwarded by Mr. G. C. Fair in 1906. Col. Lab. Rep. 1907, p. 35).

(7.) From sea-shore near New Plymouth. (Analysis by Colonial Analyst, July, 1905. Sample collected by Dr. J. M. Bell).

(8.) From Main Waitangi Spring, Poverty Bay. (Bull. No. 9 (New Series), N.Z.G.S. p. 37.)

(9.) From Kotuku, near Greymouth, 1906. (Bull. No. 9 (New Series), p. 37.)

The two analyses subjoined may be of interest.

(1.) Apparently from Booth's well (6). (Boverton Redwood, July, 1891*) :—

	Per Cent.	S.G. at 60° F.
Petroleum spirit	Nil	..
Petroleum oil (kerosene)	48·25†	0·811
Intermediate and heavy oils with solid hydrocarbons (paraffin)	51·25	..
Coke and loss	0·50	..
	100·00	

(2.) Probably from Birthday well (16). (A. F. Craig and Co. (Limited), of Paisley, 19th February, 1907.) Water = 6·18 per cent. by volume. Is easily removed by settling. Analysis of remainder :—

	Per Cent.	Sp. Gr.	F.P.	S.P.
Spirit	14·31	0·7565	..	..
Kerosene, first quality ..	32·00	0·8157	79° Fahr.	..
Kerosene, second quality ..	6·25	0·8340	76° Fahr.	..
Gas-oil	14·81	0·8662	..	27° Fahr.
Spindle-oil	8·76	0·9078	..	23° Fahr.
Refined wax	10·70	..	..	..
Residue oil from wax ..	1·80	..	..	..
Residuum	2·22	..	..	..
	90·85			

The following results of the distillation of oil from the earlier ventures may be of interest.

(1.) "Oil from well at Sugar-loaves" (New Zealand Government *Gazette*, 29th June, 1866) :—

	Sp. Gr.	Per Cent.
Oil	0·874	2·0
Oil	0·893	10·0
Oil	0·917	8·0
Oil	0·941	60·0
Solid bitumen	..	6·1
Fixed carbon	..	12·4
Ash	..	1·5
Specific gravity of crude oil, 0·962.		100·0

(2.) W. Skey (Trans., vol. vi, 1874, p. 252), "Oil from Sugar-loaves" :—

No.	Volume of Distillate upon Charge. Per Cent.	Sp. Gr.
1	2·0	0·880
2	5·5	0·888
3	5·5	0·900
4	4·0	0·910
5	8·0	0·917
6	8·0	0·926
7	12·0	0·938
8	12·0	0·930
9	13·0	0·898
10	4·0	0·908
11	8·0	0·938
	82·0	

* See also "Petroleum and its Products," vol. i, 2nd edition, 1906, pp. 104, 202, and 216.
† Equivalent to 50 per cent. by volume. Flashing-point, 78° Fahr.

Experts seem to agree regarding the excellent quality of the products which may be obtained from Taranaki oil. Redwood remarks that the kerosene distillate is of such satisfactory colour and odour as it comes from the still that it hardly requires the customary treatment with acid and alkali. He regards it as probable that a larger sample of crude oil than that submitted to him would yield 6 or 7 per cent. of solid hydrocarbons. A. F. Craig and Co. speak in similar terms of the sample examined by them, and add that in character and purity the crude oil resembles Pennsylvanian petroleum. The kerosene, however, shows a tendency to smoke in American lamps. The oil is found to be of a more complex character than that obtained at the Waitangi Oil-spring, Poverty Bay district,* since it contains 20 per cent. of benzene, which is not represented in the latter. This, however, is surface oil from which the lighter hydrocarbons have evaporated. The percentage of lubricating-oil in Taranaki petroleum is much lower, while the percentage of paraffin is much higher, than in Poverty Bay oil.

From trials with locomotives conducted on the New Zealand railways there seems no doubt that the crude oil produced at the Taranaki Petroleum Company's No. 2 and No. 3 wells forms an admirable fuel for steam-raising purposes.

(4.) *Escapes of Natural Gas.*

A considerable number of gas-vents occur in and near the New Plymouth Subdivision. The most important may be described as follows:—

(1.) Gas escapes under strong pressure from bores Nos. 2 and 3 (17 and 9 on the map of the Paritutu Survey District) of the Taranaki Petroleum Company, and is used in the furnaces of the company, a considerable saving in fuel being thereby effected. Analyses of the gas from these two wells will be found in the next section. The gas from No. 2 escapes from depths of 2,250 ft., 2,560 ft., 2,800 ft., and 3,000 ft. In No. 3 the principal escapes are from the 2,676 ft., 2,690 ft., 3,710 ft., and 3,720 ft. levels. In March, 1911, gas was struck in such great volume at 1,010 ft. and 1,535 ft. in the Taranaki Petroleum Company's No. 5 bore as to "force the silt over the top of the derrick," according to telegrams in the daily papers.

(2.) Numerous escapes are situated on the Huatoki River, near and south of the southern boundary of the subdivision. These vents have been known for many years, and, so far as can be ascertained, have continuously discharged large quantities of gas. The vents in this neighbourhood are thus described by Bell†: "On the property of Mr. A. S. Petch, a number of gas-emanations appear on a small creek, a tributary of the Huatoki. Two (about 1 chain apart) are especially conspicuous. The upper issues on the edge of the stream on the left side, while the other bubbles forth in a small pool of water filling an artificial excavation. When lighted both burn vigorously for a few minutes, with almost a foot of flame of a yellowish colour. When first discovered and somewhat opened out, the upper jet of gas is said to have burned continuously for ten days. Further ebullitions of gas on a smaller scale appear on the Huatoki, above and below the entrance of the small stream above mentioned. Much of the surface soil of this locality is composed of a curious resin-coloured peat (?), but I am not of the opinion that such strong flows of gas could be derived from this source. They are probably of more deep-seated origin. About three-quarters of a mile lower down the Huatoki Valley, on a tributary entering on the right side, other jets of gas appear like those on Petch's farm, and apparently almost equally strong. Here some advantage has been taken of the gas, a roughly made cone being placed over the vent to concentrate the gas and give a constant flame when necessary

* See Bulletin No. 9 (New Series), N.Z.G.S., pp. 37 and 38.
† "Preliminary Report on the Taranaki Oilfield," C.–14, 1909, p. 3.

for boiling water, &c., by the men working in the neighbouring fields. Still lower down the Huatoki Valley, about half a mile from the right bank of its tributary known locally as the Huatokiti, and on the property of Mr. Grooby, Frankley Road, there is a very strong ebullition of gas issuing on the edge of a tiny puddle of water in an artificial excavation in tufa. The jets flow from several small cracks occurring in an area of about 18 in. square, giving when lighted a strong flame 18 in. or 2 ft. in length, which burns without cessation unless somewhat violently extinguished." An analysis of a sample of this gas will be found in the next section.

(3.) In the neighbourhood of the Moa Petroleum Company's bore at Inglewood (22 on general map) gas is constantly escaping from a hole dug in a peaty deposit of recent geological age. A sample of this gas was analysed, with the result given below. Small escapes of inflammable gas are said to be common at Inglewood.

(4.) On Mr. Bishop's farm near the right bank of the Mangaone Stream, nearly two miles above its junction with the Waitara River, a considerable and continuous escape of gas occurs in a small swampy stream. The rocks through which the escape is taking place are the volcanic débris of the Pouakai Series. An analysis of this gas is given in the next section.

(5.) Gas is escaping at the head of a runnel on the left bank of the Mangaone Stream about a mile south of the southern boundary of the subdivision. From the close proximity of the claystones of the Onairo Series it is almost certain that this gas, an analysis of which will be found in the next section, is escaping through them; but in the hole which was dug to facilitate the collection of the gas the chief material obtained was volcanic grit, some of which was very pumiceous.

(6.) Strong escapes occur south of the southern boundary of the subdivision and about two miles due south of Junction Road on the Mangamauhete Stream, a tributary of the Manganui River, for a distance of some chains along the left bank and in the bed of the stream itself through bleached volcanic sand. An analysis of this gas is quoted below.

(7.) About 5 chains from the Inglewood Petroleum Company's bore (23 on general map) on the Norfolk Road, about three miles south of Inglewood, a fairly strong escape of gas (an analysis of which is given below) is taking place by the side of a small stream.

The following less well-authenticated or smaller escapes of gas in and near the subdivision deserve some notice:—

(i.) The reported oil-seepage and gas-escape on the Waiwakaiho River just below the railway-bridge has been dealt with in a preceding section (p. 39).

(ii.) Small gas-escapes are fairly common in the small streams in the neighbourhood of the Taranaki Oil and Freehold Company's bore (20 on map of Paritutu Survey District). Some of these escapes are possibly of deep-seated origin, but the majority no doubt result from the decomposition of superficial deposits of organic débris.

(iii.) In 1906 or 1907, on Mr. W. Davies's farm (Section 11), on the Waitangia Creek, near the dairy factory on the Junction Road, a little south-east of the junction of the Mangorei and Waiwakaiho rivers, some prospectors are reported to have obtained gas, and a distinct smell of petroleum by boring to a depth of 25 ft. On the strength of these indications the property is said to have been sold at a price considerably above its value as agricultural land. No such indications are now visible.

(iv.) On a branch of the Waitangia Creek, where it crosses and is damned up by the Junction Road near the last-named place, a few bubbles of gas and also much dark-brown scum are usually to be seen. Probably these "indications" are of no importance.

(v.) On Mr. Hosking's farm (Section 109), on the Te Arei Road, near the Sentry Hill flour-mill, gas is said to have been observed escaping in some volume during the dry weather of 1907. The writer could see none in the summer of 1910–11.

(vi.) Escapes of gas are reported to have been observed close to the brickworks near the Devon Road about a quarter of a mile on the New Plymouth side of Waitara. The writer has been unable to satisfy himself as to this occurrence.

(vii.) Gas, the composition of which is unknown, continuously escapes in small quantities from the artesian wells in Messrs. Borthwick and Son's freezing-works at Waitara.

(viii.) Gas is said to escape at a point on the big bend of the Waitara River just above the settlement of Huirangi. This occurrence could not be found by the writer.

(ix.) Near Lepperton, on Section 10, on the Manutahi Road, and about a quarter of a mile west of the railway-line, there is said to have been a strong escape of gas in a well about 50 ft. deep, sunk in the volcanic débris of the Pouakai Series. At the time of the sinking of this well, twenty-five years ago, a man is reported to have been injured by an explosion due to the ignition of the gas.

(x.) A similar accident occurred during February or March of 1908 to a man engaged in sinking a well on Mr. F. W. Cornwall's property (Section 85) on the Corbett Road, about one mile and a half north-west of the last-named locality. The well was at a depth of about 50 ft. when the explosion occurred.

(xi.) As already mentioned (pp. 27, 43), the gas-escapes described under (2) above are accompanied by a somewhat remarkable peaty deposit, analyses of which are quoted. Mounds of a very similar deposit were noted in the following places, and may be regarded as affording some evidence that they are the sites of former gas-vents. In Mangarewa Creek, on Sections 122 and 109, about 30 chains south of Trig. Station XXII, two mounds about 3 ft. high occur. It is said that in this place, when the stream was high, gas was seen escaping from under the water and was lit. On the Upper Puketotara Creek, on Mr. H. Hall's farm, near the boundary of Section 130, and about half a mile south of Trig. Station XXI, a similar mound over half a chain in diameter occurs.

(xii.) On the Waitara River for some distance above the mouth of the Mangaone Stream numerous gas-escapes, apparently too constant to have a mere superficial origin, were noted.

(xiii.) By the side of the Mangaone Stream, about 20 chains south of the large escape described above (No. 5), a rather diffuse and feeble gas-escape occurs through swampy ground.

(xiv.) A "mud volcano," the site of which was approximately half a mile south of Junction Road, where the Norfolk and Suffolk Roads now join, near the Manganui River, was noted in 1873 by Mr. C. W. Hursthouse when carrying out a survey. The Maoris told him that in 1859 a big outbreak, the noise of which could be heard at the pa on the other side of the Manganui River, threw mud over the trees for some distance. This occurrence was regarded by the Maoris as an omen of some important event—a belief confirmed by the outbreak of the Taranaki war in 1860.

(xv.) On the Bristol Road, a few chains north-east of its junction with Junction Road, in the same stream in which an oil-seepage is said to occur (see (12), p. 40) a strong escape of gas was reported during the summer of 1909–10. When the place was examined by the writer during the summer of 1910–11 only a few bubbles of gas were seen.

(5.) *Analyses of Gas.*

The following are analyses of the natural gas from the most important vents in and near the subdivision. In every case the gas was collected in clean bottles, which were corked, with a little water inside as an additional precaution, sealed, packed in an inverted position, and sent without delay to the Dominion Laboratory in Wellington.

	(1.)	(2.)	(3.)	(4.)	(5.)	(6.)	(7.)	(8.)
Methane (CH_4)	24·40	22·70	95·50	95·00	95·40	95·10	95·70	93·70
Ethane (C_2H_6)	16·30	25·80	..	..	..	..	..	..
Olefines (C_nH_{2n})	Nil	Nil	0·43	0·43	0·44	0·44	0·42	0·41
Carbon-dioxide (CO_2) ..	49·20	43·70	0·54	0·50	0·26	1·25	0·52	0·82
Oxygen (O)	1·30	1·30	0·14	0·20	0·17	0·14	0·15	0·63
Nitrogen (N)	8·80	6·50	3·39	3·87	3·73	3·07	3·21	4·44
Totals	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

Localities—

(1.) No. 2 bore, Taranaki Petroleum Company (17 on map).
(2.) No. 3 bore, Taranaki Petroleum Company (9 on map).
(3.) Petch's farm, near Carrington Road.
(4.) Bishop's farm, Mangaone Road.
(5.) Section 24, Mangaone Road.
(6.) Near Moa Petroleum Company's bore (22 on map).
(7.) Near Inglewood Petroleum Company's bore (23 on map).
(8.) Maungamauhete Stream.

For the sake of comparison the following analyses of natural gas from other parts of the world may be quoted.*

	(1.)	(2.)	(3.)
Hydrogen	1·64	0·98	..
Marsh-gas	93·35	93·07	97·70
Olefiant gas	0·35	3·26	
Carbonic oxide	0·41	..	..
Carbon-dioxide	0·25	2·18	0·28
Oxygen	0·39	..	Trace
Nitrogen	3·41	0·49	2·02
Sulphuretted hydrogen	0·20	..	0·00
	100·00	99·98	100·00

Localities—

(1.) Ohio (Findlay).
(2.) Russia (Caspian Region).
(3.) Pennsylvania (Lyon's Run, Murraysville).

It would thus appear that samples 3 to 8 have a composition agreeing with that of natural gas from other parts of the world. Samples 1 and 2, on the other hand, differ markedly in their very high carbon-dioxide content from any gas-analyses quoted by Redwood. The large quantities of carbon-dioxide in the gas from the bores at New Plymouth are probably due to the hydrocarbons becoming mixed with carbon-dioxide, evolved as a last phase of the volcanic activity which was at one time rife in the neighbourhood.

(6.) *Conclusions.*

After a study of the very imperfectly revealed geological structure of the subdivision,† and after a careful comparison of the generally unsatisfactory bore-records, the writer has come to the following conclusions :—

1. The chief oil- and gas-producing strata of the area are the rocks of the Onairo Series, which is Miocene in age.

* From "Petroleum and its Products," by Sir Boverton Redwood, 2nd edition, vol. i, pp. 248–250.
† The detailed results of the writer's geological studies are set forth in Chapter II.

2. The gas which is found escaping in considerable quantity from the rocks of the overlying Pouakai series, and the oil of which a few undoubted seepages from the same rocks occur, originated mainly or wholly in the Onairo rocks.

3. There is no evidence as to the mode of origin of the gas and oil.

4. No distinct anticlines and synclines can be distinguished in the rocks of either the Onairo or the Pouakai Series, nor are there any geological data which justify the selection of bore-sites.

5. Petrolaceous substances probably exist at or near the surface in the country to the east of the New Plymouth Subdivision.*

6. The rocks in which these petrolaceous substances exist conformably underlie the Miocene rocks, which are exposed in the subdivision and are probably over 5,000 ft. below the surface of the neighbourhood of New Plymouth.

7. Oil has been found in payable quantities on the Taranaki Petroleum Company's property.

8. The oil horizons as disclosed by boring near New Plymouth lie at approximately 1,000 ft., 2,000 ft., and 3,000 ft. below sea-level, but owing to the variable character of the strata are ill-defined, and are at varying distances from the surface in neighbouring bores.

9. The 3,000 ft. horizon is the most productive.

10. The 1,000 ft. horizon is probably of least importance, but merits more careful prospecting than it has yet had, especially near Booth's well (6).

11. The position of oil-reservoirs in the subdivision can be determined only by systematic deep boring.

12. A belt of country about three miles wide in which gas-vents occur extends from the Sugar-loaves in an east-south-east direction for at least fifteen miles.

(7.) *Recommendations regarding Future Prospecting for Oil in Taranaki.*

In view of these conclusions, the writer recommends,—

1. A thorough geological examination of the country to the east and north-east of the subdivision, in the hope that payable oil-reservoirs may there be located nearer the surface.

2. A systematic prospecting of the subdivision by means of deep bores at regular and considerable intervals. Assuming the correctness of the depths recorded at the Carrington and Norfolk Road bores (24 and 23), no bore should be abandoned as "dry" unless it has reached a depth of 3,000 ft. below sea-level without obtaining oil.

3. The systematic recording of the strata passed through in the bores, and the keeping of large and accurately labelled samples of these strata.

4. The co-operation of all parties engaged in oil-prospecting, more especially in regard to the comparison of strata passed through. The only way to insure comparable results is to secure the constant presence on the field of a competent geologist, who should examine and record all the specimens obtained.

Although geological data are very meagre, the writer would recommend as the most likely zone for exploration by deep boring the strip of gas-producing country defined above.

* For further particulars see C.–9, 1910, p. 23.

Iron-ores.

(1.) Ironsand.*

(1.) *Introductory.*

As stated in a previous chapter (pp. 27, 28), the sand-dunes and beaches of the New Plymouth Subdivision are usually composed of black sand consisting largely of magnetite. The writer did not undertake any investigations into the relative amounts of magnetite and ferro-magnesian minerals occurring in this sand. The following account of the composition and treatment of the sand is culled from a variety of sources.

(2.) *Composition of Ironsand.*

Many analyses of the Taranaki ironsand have been made from time to time. As would be expected, they show a very considerable range in composition, depending on the relative proportions of magnetite, ilmenite, ferro-magnesians, and other impurities in the samples.† The following analyses may be quoted as examples:—

——	Dominion Analyst, Rep. Col. Lab., 1903. ("Sample taken from beach," by Mr. E. M. Smith.)	*Iron and Coal Trades Review*, July, 1896.	Quoted by E. M. Smith in 1888.	Hector, Rep. G. S. 1866–67.	G. J. Snelus (Private Report).	Hector, in *New Zealand Mines Record*, July, 1900.	
Ferric oxide ..	40·68‡	67·04	52·88	82	Metallic iron 58·7	91·9‖	71·0¶
Ferrous oxide ..	36·05‡	30·17	29·60 §				
Manganese-oxide ..	0·35	0·22	0·48	..	..	..	..
Alumina	4·00	0·16	0·90	..	..	..	..
Lime	1·80	..	..	..	..	..	..
Magnesia	2·77	..	4·00	..	..	..	..
Phosphoric anhydride (P_2O_5)	0·09**	0·03	Nil	..	Phosphorus 0·015	..	..
Sulphuric anhydride (SO_3)	0·01††	..	..	..	..	..	..
Silica	3·90	0·51	3·80	8	4·600	..	..
Titanic anhydride ..	9·20	1·64	8·41	8	7·500	6·2	8·0
Oxide of cobalt ..	..	..	Trace	..	..	..	..
Sulphur	..	..	Nil	..	0·015	..	..
Water	0·25	..	..	2	0·034	..	..
Alkalies and undetermined	0·90	..	..	..	..	..	..
	100·00						

It should be noted that Skey has shown that the ilmenite cannot be separated from the magnetite either by electro-magnetic or sifting processes (see Rep. Col. Lab., 1900, p. 17)

* The writer is much indebted to Professor A. Jarman, Director of the Auckland University College School of Mines, for advice in regard to this section. † A sample of ironsand from Patea recently analysed in the Dominion Laboratory was found to contain 0·16 per cent. of vanadium. If, as is therefore probable, the New Plymouth ironsand also contains some vanadium, and if this vanadium can be retained during smelting and during the manufacture of steel, its value becomes considerable. ‡ Equivalent to metallic iron 56·87 per cent. § Equivalent to metallic iron 60·3 per cent. ‖ Equivalent to metallic iron 70·1 per cent. ¶ Equivalent to metallic iron 56·1 per cent. ** Equivalent to phosphorus 0·039 per cent. †† Equivalent to sulphur 0·004 per cent.

(3.) *History of Attempts to treat the Ironsand.*

The earliest attempt to smelt the Taranaki ironsand appears to have been made by a Mr. John Perry, a carpenter, who in 1848 erected a small furnace beside a tributary of the Huatoki River, near the Carrington Road, and succeeded in producing an inconsiderable quantity of iron, which was locally forged into small articles. In this, as in many subsequent attempts, the failure was chiefly due to the fineness of the sand.

Shortly after this some unsuccessful experiments in the same direction were made by Mr. C. Sutton.

In 1858 a lease of ironsand was granted by the Provincial Government to Captain Morshead, who endeavoured, without success, to float a company in England to treat the ironsand.

In 1869 Henochsburg and Co. erected a furnace on a site apparently quite close to that of the Bonithon Company's derrick (21 on map of Paritutu Survey District). Partial success attending this venture, the firm was extended into the Pioneer Steel Company, which, however, was apparently wound up or merged shortly afterwards into another, known as the New Zealand Titanic Steel and Iron Company (Limited). This company was formed chiefly by the exertions of Mr. E. M. Smith, the inventor of a method by which the ironsand was moulded with clay into bricks, in order to prevent the choking of the furnaces. The smelting of the ironsand by this method proved, it is said, a great success. The enterprise, nevertheless, collapsed for want of funds. After great exertions by Mr. Smith a company was floated in Wellington, which expended £20,000 in the erection of up-to-date works near the mouth of the Henui River. After the completion of the works, however, only enough capital was left for the carrying-out of one trial smelting. On the 23rd September, 1876, 3 tons 15 cwt. of pig iron was obtained. This was tested in England, and reported to be of the very best quality. After these experiments the furnace was blown out, and the works stood idle till 1884, when abortive attempts at smelting were successively made by Messrs. Hughes and Hipkins. In 1888 Messrs. Oldfield and E. M. Smith made further trials, which, on the whole, appear to have been successful, but the operations terminated in 1889, when the Bank of New Zealand acquired the furnace and plant and removed them to Onehunga, near Auckland.

In 1892 Mr. E. M. Smith obtained the sanction of the Bank of New Zealand to conduct further trials with the plant at Onehunga, the results of which appear to have been entirely satisfactory. Forty-five tons of iron were obtained, the iron running freely, the tuyères being clean, and only 2 to 3 per cent. of iron-oxide being left in the slag.

In 1896 Mr. E. M. Smith visited England with samples of the steel manufactured by himself from Taranaki ironsand. The prospects of the industry were most favourably reported on by various experts, including Mr. G. J. Snelus, F.R.S. Despite these favourable reports, however, Mr. Smith did not succeed in his efforts to float a company for the purpose of working the iron-deposits.

During 1899 the New Zealand Government tried to arrange with the Esteve Steel Company to conduct experiments in improved methods of smelting the sand, but the parties were unable to come to terms.

Mr. Smith revisited England in 1901 in company with Mr. (afterwards Sir) A. J. Cadman, and was again unsuccessful in raising capital for iron-works. Mr. Cadman, however, returned to England in order to pursue the project. Since then another attempt to float a powerful company to develop the Parapara iron-ore* and the Taranaki ironsand has failed.

It is said that at the present time a syndicate has undertaken to begin erecting plant for smelting the ironsand before April, 1912.

* Regarding the potentialities of this deposit see Bulletin No. 3, N.Z.G.S. (New Series).

(4.) *Method and Results of Smith's Patent Smelting Process.*

It may be of interest to give a short account of the process invented by Mr. E. M. Smith for the smelting of the Taranaki ironsand. The method consisted in the manufacture of briquettes from ironsand and suitable fluxes, which were also used as the binding material. The mixture employed in the manufacture of the briquettes was as follows: Ironsand, 160 parts by weight; "blue clay," 25 parts by weight; "yellow clay," 25 parts by weight.

Various analyses of the ironsand are quoted in a previous part of this section. The "blue" and the "yellow" clays were stated by Mr. Smith, in a paper read in 1896 before the Iron and Steel Institute, to analyse as follows:—

	Blue Clay.	Yellow Clay.
Silica	54·21	41·000
Alumina	31·64	23·000
Iron-oxide	8·96	9·025
Manganese	Traces	Traces
Lime	1·60	1·025
Magnesia	1·42	..
Alkalies	..	2·000
Water	2·17	24·014
	100·00	100·064

In a private report* in 1896 Mr. G. J. Snelus stated that he found the clays to contain the following substances—

	Blue Clay.	Yellow Clay.
Moisture	5·440	10·580
Sulphur	1·879	0·018
Phosphorus	0·049	0·016
Iron	1·870	9·610

and therefore advised that the yellow clay, which was probably yellow tufa of the Pouakai Series of this bulletin, should be used in the manufacture of the briquettes rather than the blue clay, which was probably a claystone of the Onairo Series, since by this means the presence of an excess of sulphur and phosphorus in the pig iron would be avoided. The following are the results of analyses of pig iron and bar iron produced by Smith's process:—

	Pig Iron.		Bar Iron.
	Smith (Paper read before Iron and Steel Institute).	Snelus.	Smith, *loc. cit.*
Iron	94·09	92·877	98·94
Manganese	Traces	0·200	Traces
Titanium	1·00	0·245	0·21
Silicon	2·12	3·270	..
Sulphur	0·02	0·136	Traces
Phosphorus	..	0·227	..
Combined Carbon	2·33	0·850	0·46
Graphite		2·200	
Loss and undetermined	0·44	..	0·39
	100·00	100·005†	100·00

*This report was published in the *New Zealand Mines Record*, vol. iv, 1900–1, pp. 47–49. See also vol. v, 1901–2, pp. 410–417.

† Apparently there is a small error in one of the percentages quoted, thus making the sum 0·005 too great.

The pig iron was described as a good grey, fairly granular, and extremely tough foundry iron, chilling with a clean surface. A fragment when struck on the anvil was found to flatten out. Mr. Snelus remarks that it contains too much phosphorus and sulphur to be used in the acid Bessemer or Siemens processes, but considers that the greater part of these impurities comes from the blue clay used in the manufacture of the briquettes. The quality of the castings was most favourably reported on by experts. The bar iron was of excellent quality, being very fine-grained and malleable.

Mr. Smith also found that, having smelted the ironsand contained in the briquettes, the liquid metal, if run into a ladle containing tarred ironsand in the proportion of 4 cwt. to each ton of molten metal, would melt and absorb the ironsand, resulting in a gain in weight of 3 cwt. per ton. The cost of the manufacture of pig iron superior in quality to the best Scotch was found to be £2 7s. 3d. per ton. In making wrought iron he found that tarred ironsand could be added in the puddling-furnace in the proportion of 50 per cent., and in the same proportion when making steel by the Siemens open-hearth furnace, resulting in an additional gain of 7 cwt. per ton. By this special treatment bar iron equal in quality to best Barrow hæmatite iron (B.B.H.) could be produced for £7 per ton. The manufactured wrought iron, when charcoal was used in the puddling-furnace, stood a tensile stress of 52 tons (?) to the square inch.

The by-products obtained from the slag, in the form of bricks, slag cement, slag blocks, and ground slag to be used as a fertilizer, were all regarded as of considerable value. The fertilizer was estimated to have the following approximate composition :—

Lime (soluble in acids)	40·0
Alumina ,, ...	12·0
Silica ,, ...	42·0
Magnesia ,, ...	2·0
Manganese ,, ...	Traces
Titanium ,, ...	1·0
Iron-oxide ,, ...	2·0
Alkalies ,, ...	1·0
	100·0

(5.) *Remarks on the Economic Possibilities of the Ironsand.*

It will be noted that no mention is made of phosphorus in the analysis quoted above, yet it is on account of its phosphate-content that basic slag is employed as a fertilizer. Slag blocks, though durable, are usually too slippery for paving-blocks, and are at present not likely to find any market in the neighbourhood of the proposed iron-works. Slag cement is, at the best, far from equal to Portland cement, and could hardly be expected to find a ready sale in New Zealand, where very good cement can be cheaply made.

It appears, therefore, that the by-products referred to above should not be counted on in arriving at conclusions as to the economic possibilities of the ironsand.

Some doubt must also be expressed as to whether the samples of ironsand, analyses of which are quoted above, were true average samples. In some places, as, for example, in the neighbourhood of Paritutu, owing probably to the prevailing tidal currents, there appear to be very large accumulations of almost pure magnetic ironsand. Along the open beaches, however, and on the sand-dunes, the heavier magnetite and ilmenite grains are frequently sorted out by the action of wind and waves, and form a thin covering to a more heterogeneous sand. It would therefore be advisable, before any erection of smelting-works is undertaken, to carry out a very thorough and exhaustive sampling of the ironsand deposits of the subdivision. In this sampling mere surface material should not be allowed to predominate unduly, but the character of the sand from various depths in the deposits should be fully taken into account.

(II.) LIMONITE.

Deposits of bog iron-ore are found in places in the western portion of the New Plymouth Subdivision, in the area occupied by the Pouakai Series, from the iron-bearing minerals of which the ore has been derived. They are most noticeable near Urenui, in the country in the neighbourhood of the southern part of Smart Road, and in the low country to the west of Burton's Hill. The deposits apparently are never more than 2 ft. or 3 ft. in thickness, and occur only in small patches. From an economic standpoint, therefore, the limonite-deposits do not call for further notice.

Materials for Roadmaking.

In the western portion of the subdivision abundant road-metal is obtained by breaking the volcanic boulders, which are either quarried, more especially in the small hills near Lepperton, or are carted from the beds of streams or from the boulder-strewn portions of the sea-front.

In the greater part of the Waitara Survey District, where the volcanic rocks are poorly developed or absent, considerable difficulty is experienced in obtaining satisfactory road-metal. The quartzose conglomerate furnishes a material which is excellent, except that the extreme hardness of the pebbles causes rapid wearing-out of horse-shoes. The calcareous concretions which are frequently abundant in the Onairo rocks make a good road-metal, more especially where they contain abundant fossils.

Building and Pottery Materials.

The volcanic rocks of the Pouakai Series would form a good building-material were it not that the labour of trimming is so considerable.

Near Waitara a claystone of the Onairo Series, and near New Plymouth a fine tufa of the Pouakai Series, have for many years furnished raw material for brick-making.

On the Smart Road considerable deposits of exceedingly decomposed and bleached volcanic rock occur. Similar deposits are also to be found near the upper waters of the Huatoki Stream, whence they extend at intervals towards the base of the Pouakai Range.

The clay from Smart Road is said to have been tested by experts, and reported upon very favourably, as a material for the manufacture of the finer kinds of pottery. Analyses of this clay are as follows:—

	(1.)	(2.)
Silica (SiO_2)	36·33	35·48
Alumina (Al_2O_3)	29·78	23·39
Ferric oxide (Fe_2O_3)	1·82	3·48
Lime (CaO)	0·07	0·98
Magnesia (MgO)	0·37	0·28
Potash (K_2O)	0·25	1·01
Soda (Na_2O)	1·31	0·68
Titanium-dioxide (TiO_2)	1·35	1·30
Carbonic anhydride (CO_2)	Nil	Nil
Moisture lost at 100° C.	9·32	12·22
Combined water and organic matter	19·40	21·18
	100·00	100·00

(1.) So-called "kaolin." (2.) "Impure kaolin."

APPENDIX.

LIST OF TARANAKI OIL-WELLS.

Arranged as far as possible in chronological order. (The numbers in the first column correspond to those used on the maps.)

No.	Ordinary Name.	Date or Approximate Date of Commencement.	Date of Abandonment or Cessation of Boring.	Greatest Depth reached (Feet).	Owners.	Greatest Oil-output, and other Remarks.
1	Alpha Well, or "Oil or London"	End of 1865	Near end of 1867	180 (shaft for first 60 ft.)	Carter and others. Sold 1867 to Taranaki Petroleum Company	80 gallons a day.
2	Victoria Well, or "Oil or Dublin"	May 24, 1866	June, 1867	516	People's Petroleum Company	..
3	Beta Well, or "Oil or Edinburgh"	May or June, 1867	June, 1868	684	Taranaki Petroleum Company	40 gallons in ten or twelve hours.
4	No. 1 Well (beach near Mikotahi)	..	..	310	Taranaki Petroleum Company	..
5	No. 2 Well	Sunk during 1866	..	318	Taranaki Petroleum Company	..
6	Booth's Well and No. 1 Well	Jan. 8, 1891	May, 1891	930	New Zealand Petroleum and Iron Syndicate (Limited) and Samuel Syndicate	Four barrels a day.
7	No. 2 Well (of Samuel Syndicate)	..	..	1,100	Samuel Syndicate	Ten barrels a day.
8	No. 3 Well, or Herekawe or Mace's Bore	..	Oct. 26, 1895	1,354	Samuel Syndicate	No oil.
9	No. 4 Well, No. 3 Well of present Taranaki Petroleum Company, or "Samuel's Bore"	Nov. 11, 1895	Still boring	3,841 in May, 1911	Samuel Syndicate	Flowing oil.
10	McColl's Bore	1896 (?)	1896 (?)	Probably less than 500	P. McColl	No oil; pobably two bores were sunk.
11	No. 5, or Putt's, Well	Feb. 16, 1898	April 13, 1898	2,053	Samuel Syndicate	One barrel per day.
12	No. 6, or Okey's, Well	April 20, 1898	Aug., 1898	302	Samuel Syndicate	No oil; volcanic boulders not penetrated.
13	No. 7, or Veale's, Well	Aug. 23, 1898	Mar. 8, 1899	1,345	Samuel Syndicate	No oil.
14	No. 8 Bore	June 8, 1899	Oct. 13, 1900	2,052	Samuel Syndicate	Only "shows" of oil.
15	No. 9 Bore	Dec. 10, 1900	Aug. 10, 1901	1,055, or possibly 1,080	Samuel Syndicate	No oil.
16	No. 1, or Birthday, Well of Taranaki Petroleum Company	April, 1904	Temporarily abandoned	2,345	Adelaide Syndicate, Moturoa Petroleum Company, Taranaki Petroleum Company	Considerable amount of oil obtained at various times.
17	No. 2 of Taranaki Petroleum Company, or Roy's Well	Dec., 1906	Jan. 5, 1910	3,030	Taranaki Petroleum Company	5th June, 1910, to 8th January, 1911, 230,000 gallons. Well still flowing.
18	No. 4 of Taranaki Petroleum Company	Jan. 14, 1907	Oct. 14, 1907	1,678	Taranaki Petroleum Company	Apparently no oil.
19	Omata Bore	Mar. 2, 1907	Nov., 1907	1,060	New Plymouth Petroleum Company	Very slight indications.
20	Vogeltown, or Ballock's, Bore	June, 1907	Dec., 1909	1,385	Taranaki Oil and Freehold Company (Limited)	Traces at various levels.
21	Bonithon Bore	Middle of 1907	End of 1908	3,005	Bonithon Freehold Petroleum Company	Possibly traces of oil.
22	Moa Bore	Aug., 1907	Jan., 1908	460	Moa Petroleum Company	Very slight traces of oil.
23	Norfolk Road Bore	Sept., 1907	Aug. 15, 1908	2,500	Inglewood Oil-boring and Prospecting Company	Traces of oil.
24	Carrington Road, or Hadley's, Bore	Nov. or Dec., 1907	Still boring	3,180 or more	New Zealand Standard Oil Company (Limited)	Traces.
25	No. 5 Bore of Taranaki Petroleum Company	Nov., 1910	Boring continues	1,745 or more	Taranaki Petroleum Company	Much gas, but no oil as yet.*

* See note on p. 35.

INDEX.

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By Authority: John Mackay, Government Printer, Wellington.—1912.

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TABULAR COMPARISON OF RECORDS OF BORES.

EXPLANATION.—The records are compiled from the following sources (the numbers being those used in the first line of the table):—(1.) Hector, Rep. G.S., 1866–67. (3.) Newspaper reports. (4.) Hector, Rep. G.S., 1866–67. (5.) Hector, Rep. G.S., 1866–67. (6.) Correspondence supplied by Mr. F. P. Corkill. (8.) Samples in New Plymouth Museum. (9.) Samples in New Plymouth Museum; McKay's Report, C.-9A, 1898; data from secretary; diaries in possession of Taranaki Petroleum Company; samples obtained by Taranaki Petroleum Company. (11.) Samples in New Plymouth Museum; McKay's Report, C.-9A, 1898; diary lent by Mr. F. P. Corkill. (12.) Diary lent by Mr. F. P. Corkill, and letter from Mr. Samuel to Mr. G. C. Fair. (13.) Samples in New Plymouth Museum; diary lent by Mr. Corkill, and letter from Mr. Samuel to Mr. G. C. Fair. (14.) Diary lent by Mr. Corkill, and letter from Mr. Samuel to Mr. G. C. Fair. (15.) Same as (14). (16.) Diaries in possession of Taranaki Petroleum Company, and portions of log lent by Mrs. G. C. Fair. (17.) Notes from secretary; diaries and samples in possession of company. (18.) Notes from secretary. (19.) Log supplied by Mr. E. Trythall. (20.) Samples and notes supplied by Mr. Balloch. (21.) Samples in possession of Mr. W. H. Saxton; log supplied by driller. (22.) Notes from Mr. T. Nicholls. (23.) Notes supplied by secretary. (24.) Samples and notes in possession of the company (which is remarkable for keeping extensive records and copious samples). (25.) Samples in possession of the company.

While not constructed strictly according to scale, the records of the different bores are placed in approximately their correct relative positions. The horizontal lines mark sea-level and depths of 1000 ft., 2000 ft., and 3000 ft. below sea-level. From considerations of space the word "feet" is omitted after the figures showing depth, and the following abbreviations are used:—Abt. = about, abund. = abundant, agg. = agglomerate, app. = apparently, bldrs. = boulders, $CaCO_3$ = carbonate of lime, calc. = calcareous, carb. = carbonaceous, cem. = cemented, conc. = concretion, cong. = conglomerate, cont. = containing or contains, clyst. = claystone, dec. = decomposed, f. = fine or fine-grained, fossilif. = fossiliferous, grau. = grauwacke, interb. = interbedded, lap. = lapilli, mic. = micaceous, occ. = occasionally, peb. = pebbles, poss. = possibly or possible, prob. = probable or probably, qu. = quartz, ser. = series, snd. = sand, sndst. = sandstone, surf. = surface, u. = upper, usu. = usually, volc. = volcanic, w. = with. The signs * and † are used to direct attention to oil and gas occurrences respectively.

Number of well in chronological list (see Appendix).	1	3	4	5	6	21	25	18
Ordinary name of well.	Alpha Well.	Beta Well.	—	—	Booth's Well.	Bonithon Bore.	No. 5 Well, Taranaki Petroleum Company.	No. 4 Well, Taranaki Petroleum Company.
Height above sea-level (in feet).	10.	About 10.	10.	20.	About 10.	44·0.	About 50.	78·45.
	Surface—60 agg.			Surface—10 snd. 10–30 agg.	Surface—140 tufa w. occ. beds of bldrs. of no great thickness.	Surface—8 soil & subsoil. 8–12 water-worn peb. prob. old river-bed. 12–64 grey tufa.	Surface—50 only one sample of brown dec. volc. rock. 50–100 andesite bldrs.	Surface—46. No record. 46–61 tufa. 61–98 bldrs.
SEA-LEVEL.	† At 20 gas. * At 44 oil. Below 60 no record of strata. * At 80 oil. * At 180 oil. At 180 bottom of well.	* At 80 oil. * At 91 good flow of oil for short time. * At 390 oil indications. * At 510 oil indications. At 684 quasr. cong. At 684 bottom of well.	* At 254 patch of grey ferruginous tufa charged w. oil. At 310 bottom of well.	[illegible]–125 tufa. 125–145 agg. At 318 bottom of well.	* At 140 slight show of oil † and moderate quantity of gas. 140–350 no record of strata. 350 at this depth bore was prob. in Onairo rocks. * At 350 seam of rock saturated with petroleum was † passed through. Stronger gas occ. than heretofore. At 700 in "very hard rock," possibly a calc. conc. A little below this struck * water w. consid. volume of gas. At 800 spring of warm bitter water. * At 870 good show of oil. * At 885 good show of oil. * At 900 rock "saturated † w. gas & oil." * At 915 oil estimated at 2 to 4 barrels per day. At 930 bottom of well.	64–91 snd. cont. qu. felspar & mica, also ferro-magnesian minerals & magnetite. 91–100 same as last, but coarser. 100–110 same as last, but coarser. 110–160 volc. bldrs. more dec. w. increasing depth. 160–195 dec. tufa. 195–315 clyst. of Onairo Ser. begins between these depths. 315–320 calc. conc. which shut off the water. 320–700 very f. clyst. At 480 calc. conc. 3 ft. thick. At 548 calc. conc. 4 ft. thick. At 676 calc. conc. 3 ft. thick. 700–1700 f. grey slightly sndy. clyst. At 740 calc. conc. 3 ft. thick. At 910 calc. conc. 3 ft. thick.	100–170 coarse tufa. † At 200 gas small. 170–250 tufa & bldrs. app. mixed. 250–783 very f. blue clyst. App. in u. surf. of Onairo Ser. About 460 conc. † At 710 gas small. About 750 conc. 783–810 sndst. † At 800 gas small. 810–1631 clyst. At 873 calc. conc. At 945 calc. conc. † At 1010 strong explosive gas.	98–197 no record. 197–744 app. clyst. (described as "papa"). At 542 calc. conc. At 652 calc. conc. 744–798 sndst. 798–1539 "papa," prob. clyst.
1000 ft. below sea-level.						At 1265 calc. conc. * At about 1480 app. traces † of gas & oil. 1700–1730 cong. 1730–1920 clayey sndst. * At 1740 good shows of oil † & gas. At 1774 gas & oil. † At 1896 strong gas. 1920–1950 cong. & soft sndst. * w. shows of oil & a little † gas. 1950–2091 fine clyst.	At 1047 calc. conc. At 1160 calc. conc. At 1325 calc. conc. At 1362 calc. conc. † At 1535 strong explosion of gas. At 1535 calc. conc. At 1578 calc. conc. At 1621 calc. conc. At 1630 fossilif. coarse snd. 1631–1714 clyst. w. conc. peb. & snd. 1714–1729 sndy. clyst. 1729–1745 clyst. w. conc. Boring continues, May, 1911.	1539–1678 app. snd. At 1678 bottom of well.
2000 ft. below sea-level.						* At 2086 small seam oil & † gas. 2091–2140 grey sndst. * At 2100 good show oil & † gas. 2140–2152 clyst. 2152–2329 sndy. clyst. * At 2247 small shows oil & † gas. 2329–2422 clyst. 2422–2480 sndy. clyst. † At 2480 increase in gas. 2480–2537 clyst. At 2521 calc. conc. 2537–2592 sndy. clyst. 2592–2610 clyst. 2610–3005 sndy. clyst. † At 2647 pressure of gas equal to 50 lb. to sq. in. † At 2741 pressure of gas equal to 45 lb. to sq. in. † At 2763 pressure of gas equal to 54–60 lb. to sq. in. 3005 bottom of well.		
3000 ft. below sea-level.								

Number of well in chronological list (see Appendix).	9	15	17	11	16	14	20	8
Ordinary name of well.	No. 3 Well, Taranaki Petroleum Company.	No. 9 Well, Samuel Syndicate.	No. 2 Well, Taranaki Petroleum Company.	No. 5 Well, Samuel Syndicate.	No. 1 ("Birthday") Well, Taranaki Petroleum Company.	No. 8 Well, Samuel Syndicate.	Vogeltown Bore, Taranaki Oil and Freehold.	No. 3 (Herekawe) Well, Samuel Syndicate.
Height above sea-level (in feet).	55·15.	About 50.	56·7.	About 80.	57·0.	About 70.	168.	About 100.
	Surface—250 tufa & fragments various volc. rocks.	Surface—107 red clay dec. volc. rock.	Surface—45 snd. 45–60 clay.	Surface—76 red volc. earth & tufa w. much ironsand. 76–127 carb. tufa w. crystals of hornblende.		Surface—30 yellow clay. 30–85 tufa & small lap.	Surface—40 clay. 40–66 f. tufa w. some clay. 66–117 agg. At 88 much carbonized wood. * At 112 small show oil. 117–135 f. tufa. 135–218 agg.	Surface—100 agg. 100–150 agg. w. clyst. app. poss. from isolated lump in agg.
SEA-LEVEL.	250–275 fragments of dec. volc. rocks. 275–300 sndy. clyst. 300–350 f. snd. 350–810 sndy. clyst. 810–850 mic. quasr. sndst. 850–915 sndy. mic. clyst. * At 900 oil. *† At 908 gas & oil. 915–1000 sndy. clyst. * At 960 oil. 1000–1150 yellowish slightly sndy. mic. sndst.	107–240 lap. & tufa. At 129 layer of bldrs. At 240 layer of bldrs. At 275 app. small seam clyst. 345–690 clyst. w. occ. calc. con. 690–922 clyst. w. seams of sndst. At 855 calc. conc. At 880 calc. conc. 922–925 clyst. At 925 calc. conc. 925–999 sndst. † At 960 gas. At 970 calc. conc. 999–1055 clyst.	60–70 tufa. 70–88 dec. volc. & tufa. 88–98 bldrs. 98–118 tufa & dec. volc. 118–141 tufa & agg. w. seams of magnetite & ferro-magnesian minerals. 141–477 no record. According to Mr. O'Dowda, the driller, the Onairo Ser. was entered about 250 down. 477–965 clyst. At 580 calc. conc. 2 ft. thick. At 640 calc. conc. At 776 calc. conc. 4 ft. thick. At 796 calc. conc. 1 ft. thick. At 820 calc. conc. At 840 calc. conc. 2 ft. thick. At 846 calc. conc. 2 ft. thick. At 869 calc. conc. 965–1039 clyst. & snd. 1039–1046 snd. 1046–1058 clyst.	127–187 fragments of various volc. rocks. 187–400 mic. snd. prob. u. surf. Onairo Ser. 400–600 sndy. clyst. 600–940 clyst. w. calc. conc. * At about 915 traces of oil † & gas. 940–1940 no record.	† At 800 gas said to have occurred in great volume.	85–103 clay. 103–135 tufa & lap. 135–176 volc. bldrs. 176–195 small lap. 195–795 clyst. marks u. surf. Onairo Ser. At 309 calc. conc. At 504 calc. conc. At 576 calc. conc. At 735 calc. conc. At 775 calc. conc. 795–988 sndy. clyst. At 800 a few peb. Between 908 & 913 calc. conc. *† At 913 slight sign of gas & oil. At 960 calc. conc. At 988 calc. conc. 988–1118 clyst.	218–239 clay (dec. tufa). 239–255 agg. 255–588 clyst. w. calc. conc. about every 10 ft. * At 449 oil. * At 475 oil. * At 492 oil. * At 574 oil. 588–604 sndst. 604–657 "rock" poss. means that calc. conc. abund. here. * At 657 app. good show of oil. 657–659 cong. 659–667 clyst. 667–669 cong. 669–740 hard clyst. At 670 much lignite. *740–818 sndst. w. good show oil. 818–975 sndy. mic. clyst. * At 900 show of oil. *975–980 grn. snd. w. oil. 980–1385 f. snd. w. many conc. * At 1160 show of oil.	150–250 coarse tufa cont. qu. crystals which were prob. derived from old sedimentaries. 250–300 grn. fossilif. snd. w. crystals of qu. biotite, muscovite, felspar. Prob. marks u. surf. Onairo Ser. 300–500 f. mic. sndst. 500–800 clyst. mic. & in places cont. qu. peb. Fragments of volc. in sample from this depth prob. fell in from above. 800–900 snd. w. water-worn peb. of qu. grau., &c. 900–1354 clyst. rather mic. in places.
1000 ft. below sea-level.	* At 1358 oil. * At 1392 oil. 1550–1680 grey sndy. clyst. * At 1675 oil. 1680–1900 yellow sndy. clyst. At 1824 calc. conc. * At 1890 some oil pumped from top of water. 1900–2000 f. snd. * Between 1900 & 1986 oil & gas. 1976 bottom of well as drilled by Samuel. Oil equal to 6 galls. per day obtained by him at this level. This oil is now shut off. †2000–2020 rather coarser snd. 2020–2094 sndy. clyst. At 2045 calc. conc.	At 1055 or 1080 bottom of well.	1058–1110 clyst. & snd. 1110–1113 calc. conc. 1113–1141 soft dark clay passing into sndy. fossilif. clyst. †1141–1220 grey clay & snd. gas increasing in strength. At 1170 seam of qu. peb., one said to have cont. gold. †1220–1340 snd. & clay. Good show gas about 1270. 1340–1405 clay. 1405–1430 clay & snd. 1430–1460 dark clay. 1460–1476 clyst. & snd. 1476–1480 calc. conc. 1480–1508 sndy. clay. 1508–1510 calc. conc. 1510–1633 blue clyst. *†1633–1855 sndy. clyst. w. large flow of gas & a little oil at 1680. At 1650 small oil seepage. † At 1754 gas very strong. 1855–1925 snd. * At 1872 show of oil. 1925–2081 sndy. clyst. † At 2000 gas.	1940–2053 soft sndst. 1960–1963 calc. conc. * At 1975 good show oil & gas. * At 1991 good show oil & gas. * At 2000 good show oil & gas. 2002–2020 sndst. harder. At 2053 bottom of well.	2011–2070 sand & clay interb., one thin band of snd. shows oil.	*† At 1089 calc. conc.; signs of gas & oil. 1118–1780 sndy. clyst. * At 1360 slight signs oil. *† At 1385 slight signs of gas & oil; between 1385 & 1388 calc. conc. * At 1410 slight sign oil. * At 1475 slight sign oil. *† At 1600 good signs oil & much gas. *† At 1710 small eruption gas & a little oil. † At 1730 explosion of gas & oil. At 1759 small calc. conc. 1780–1784 sndst. & cong. 1784–1808 clyst. app. w. seams of sndst. 1808–1860 soft sndst. 1860–1888 sndst. w. some seams of clyst. At 1888 calc. conc. 1888–1975 sndst. cem. w. $CaCO_3$ towards bottom. At 1926 calc. conc. At 1935 small calc. conc. Between 1955 & 1958 seam of clyst. 1975–1985 clyst. 1985–2052 sndy. clyst. At 2052 bottom of well.	At 1289 much lignite. At 1385 bottom of well.	At 1300 calc. conc. At 1354 bottom of well.
2000 ft. below sea-level.	At 2094 calc. conc. 2094–2298 blue & grey clyst. * At 2128 small seam oil. At 2133 little salt water. † At 2157 gas. At 2178 calc. conc. *† At 2289 gas & oil. 2298–2398 prob. sndst. cem. w. $CaCO_3$, locally known as "granular limestone." 2398–2803 sndst. † Between 2570 & 2574 very strong gas occ. * At 2570 oil-seam which yielded 90 barrels. † At 2676 gas strong. † At 2690 gas strong. * At 2800 oil. 2803–3029 sndy. clyst. w. calc. conc. at intervals. At 2823 lump of galena 2 in. in diameter is said to have been obtained. 3029–3180 clyst. cont. some mica.		2081–2086 hard blue clay. 2086–2111 sndy. clyst. 2111–2244 sndst. * At 2117 oil-vein. * At 2123 oil-vein. *† At 2175 oil & gas. *† At 2183 vein of gas & oil. † At 2192 gas. * 2200–2205 oil-vein. 2244–2343 grey clyst. becoming slightly sndy. near bottom. † At 2250 gas strong. At 2320 calc. conc. 2343–2500 sndst. w. variable amount of clay, varying also in coarseness of snd. grains. 2500–2600 f. sndy. clyst. At 2550 calc. conc. † At 2560 gas strong. * At 2570 very fine flow of oil. 2600–2700 f. snd. 2700–2800 slightly sndy. grey clyst. † At 2800 gas strong. 2800–2920 snd. At 2870 calc. conc. 2920–2928 f. grey clyst. 2928–2936 sndst. 2936–2995 clyst. w. occ. conc. 2995–3000 sndst. † At 3000 gas strong. 3000–3030 clyst. w. conc. 3030 bottom of well.		2070–2095 alternating bands of sndst. & dark sndy. clay. 2095–2140 grey sndst. of varying hardness with some clay. † At 2125 gas. 2140–2182 grey snd., harder between 2155 & 2162, & between 2176 & 2182. * At 2160 good oil show. †* At 2171–2176 much gas & a small show of oil. *2182–2188 grey clay & soft † snd. Good show of oil; gas very strong. *2188–2218 grey snd. harder in places. † At 2188 gas. † At 2211 gas. † At 2218 gas. 2218–2242 whitish clay. * At 2224 show of oil. * Between 2233–2242 good oil. 2242–2256 snd. * At 2256 show of oil. Main supply of oil app. between * 2250 & 2300. Bottom of well at 2320.			
3000 ft. below sea-level.	* At 3088 oil, main source of present supply. 3180–3195 clyst. slightly sndy. 3195–3199 clyst. 3199–3204 mic. snd. 3204–3424 very f. clyst. 3424–3457 brown clyst. 3457–3489 sndy. clyst. 3489–3640 f. clyst. 3640–3808 sndy. clyst. † At 3710 seam of peb. & very strong explosion of gas. 3808–3841 f. clyst. May, 1911. Boring continues.		Flowing oil.					

Number of well in chronological list (see Appendix).	19	13	12	24	22	23
Ordinary name of well.	Onaata Bore, New Plymouth Petroleum Company.	No. 7 (Veale's) Well, Samuel Syndicate.	No. 6 (Okey's) Well, Samuel Syndicate.	Carrington Road Bore, N.Z. Standard Oil Company.	Moa Bore.	Norfolk Road Bore.
Height above sea-level (in feet).	About 100.	331.	275.	650.	657.	780.
	Surface—100 dec. volc.	Surface—112 dec. tufa w. many carb. remains, sometimes forming an impure peat. 112–138 f. tufa. 138–205 coarse lap. & volc. bldrs. 205–230 large bldrs. w. some lap. 230–272 f. lap. w. fragments of clyst. At 260 larger bldrs. 272–350 lap.	Surface—90 volc. bldrs. & clay. 90–167 coarse lap. w. clay. 167–302 lap. & bldrs. At 200 thin seam of clay. At 302 bottom of well.	Surface—10 dec. tufa. 10–20 tufa volc. bldrs. & dec. wood. 20–40 rather dec. coarse tufa. 40–98 tufa & f. lap. usu. undec. & cont. consid. percentage isolated crystals magnetite & water-worn pebbles volc. rock. 98–170 consid. dec. tufa usu. rather coarse. 170–208 agg. cont. app. good many water-worn bldrs. 208–230 undec. tufa & a good many bldrs. 230–253 river snd. cont. qu. & magnetite crystals. Some bldrs. 253–264 larger bldrs. 264–514 river snd. w. larger bldrs. & occ. thin beds of silt & tufa. 514–560 f. tufa & lap. 560–930 mic. clyst. rather sndy.	Surface—250 agg. & tufa. 250–300 "brown shale" * said to cont. oil. 300–400 clyst. At 400 bottom of well.	1–10 tufa. 10–35 dec. tufa. 35–56 hard grey tufa. 56–75 agg. 75–275 rock described as "exceedingly hard f. sndst. w. occ. coarser seams," poss. a tufa. † At 138 gas. † At 149 gas. † At 195 gas. At 227 layer of vegetable matter. 275–292 referred to as "papa," may be clyst. of Onairo Ser. or very f. tufa. 292–318 agg. † At 300 gas. 318–355 tufa. 355–405 agg. * At 395 slight show oil. * At 405 slight show oil. 405–470 app. rapid alternations of tufa & dec. agg. w. frequent lumps of "papa" (clyst. ?). 470–1178 app. clyst. of Onairo Ser. Is referred to in log as "papa." At 750 sndy. seam.
SEA-LEVEL.	100–270 agg. 270–340 tufa & lap. 340–375 agg. *375–510 hard sndst. showing oil. Poss. u. surf. Onairo Ser. 510–515 light-blue clyst. 515–681 clyst. w. large bldrs. * From local information seems prob. these were calc. conc. Throughout this depth strata are frequently marked as showing oil. *681–700 snd. Show of oil. 700–862 f. clyst. *† At 785 oil & some gas. *† At 815 oil & some gas. *†862–1000 sndst. Frequent shows of gas & oil. 1000–1010 bldrs. (? conc.) & f. snd. *†1010–1060 clyst. w. gas & oil. At 1060 bottom of well.	350–360 tufa. 360–385 lap. & tufa. * At 384 app. small seam oil. 385–410 "Quicksand" mic. sndst. prob. u. surf. Onairo Ser. 410–1000 clyst. 1000–1010 fossilif. clyst. w. many peb. qu., grau., &c. 1010–1015 clyst. 1015–1032 clyst. w. peb. qu., grau., &c. 1032–1335 clyst. At 1065 seam of peb.		930–1200 calc. clyst. At 1059 calc. conc. At 1150 calc. conc. 1200–1210 f. fossilif. cong. 1210–1220 f. greenish mic. sndst. 1220–1230 v. f. fossilif. cong. 1230–1240 f. fossilif. mic. sndst. 1240–1250 cong. 1250–1280 f. greenish fossilif. snd. 1280–1310 f. rather calc. clyst. w. conc. 1310–1380 f. mic. snd. w. calc. conc. at 1300 & 1375. * At 1325 slight show of oil. 1380–1396 sndy clyst. At 1391 calc. conc. 1396–1438 fossilif. sndst. w. partings of sndy clyst. At 1435 calc. conc. 1438–1480 fossilif. sndst. w. seams of cong. 1480–1530 fossilif. calc. clyst. w. peb. & conc. 1530–1540 fossilif. cong. 1540–1563 fossilif. calc. clyst. At 1557 calc. conc. 1563–1620 sndy clyst. 1620–1630 fossilif. cong. 1630–1640 grey fossilif. sndst. 1640–1645 clyst. At 1642 calc. conc. 1645–1730 calc. clyst. w. calc. conc.		At 840 sndy. seam. † At 1080 large gas occ. † At 1121 large gas occ. 1178–1270 f. grey snd. 1270–1441 f. grey snd. interb. w. clyst. occ. cont. thin calc. conc. † At 1441 gas occ. 1441–1640 sndy. clyst. † At 1500 strong gas occ. 1640–1825 snd.
1000 ft. below sea-level.		1335–1345 sndy. clyst. At 1345 bottom of well.		At 1666–1686 more sndy. w. qu. pebbles, &c. *At 1671 trace of oil. At 1677 calc. conc. 1730–1795 fossilif. sndst. At 1768 & 1775 calc. conc. 1795–1840 fossilif. sndy. clyst. w. occ. bldrs. 1840–1874 fossilif. snd. 1874–1900 sndy. clyst. At 1928 calc. conc. 1900–2000 f. sndy. clyst. 2000–2015 grey calc. & mic. clyst. 2015–2033 sndy. clyst. † Small gas occ. 2033–2063 f. clyst. w. calc. conc. 2063–2100 sndy. clyst. w. occ. peb. qu., &c. † Strong gas occ. 2100–2170 f. sndy. clyst. 2170–2250 f. grey mic. snd. 2250–2280 clayey sndst. 2280–2300 mic. sndst. *At 2300 oil, small. At 2323 narrow seam cong. *At 2336 oil. At 2338 calc. conc. *At 2351 oil. 2300–2400 fossilif. cong. w. clyst. Abt. 2380 fragments of fossilif. carb. clyst. 2400–2440 rather f. mic. sndst. 2440–2500 clayey fossilif. sndst. 2500–2510 fossilif. cong. 2510–2730 snd.		1825–1915 clyst. 1915–2020 sndy. clyst. 2020–2100 clyst. † At 2020 gas. † At 2152 gas. At 2500 bottom of well.
2000 ft. below sea-level.				2730–2900 f. clyst. 2900–2950 f. brown clyst. 2950–3025 f. mic. sndst. 3025–3080 rather sndy. brown clyst. 3080–3240 f. sndy. clyst. *At 3100 small seam oil. Boring continues.		
3000 ft. below sea-level.						

P.G. MORGAN.
DIRECTOR

GEOLOGICAL SKETCH MAP OF PORTION OF TARANAKI DIVISION

(including a small portion of Pirongia Division, Auckland Land District)

Scale of Miles

1 ½ 0 5 10

— Reference —

- Roads ..... shown thus
- Trigonometrical Stations ..... " C ○ 1841'
- Edges of Bush ..... "
- Swamp ..... "
- Railways ..... "
- Oil wells - producing ..... "
- " " drilling ..... "
- " " rig up or partially in position but not operating or producing ..... "
- Oil Wells - abandoned ..... "
- Oil seepages ..... "
- " " - reported ..... "
- Gas vents ..... "
- " " - reported ..... "
- Areas in which conical hills occur ..... " Co.

AUCKLAND LAND DISTRICT

SEA

TASMAN

Mokau River

Mohakatino River

Awakino River

Awakino Village

Mokau

Marxville

Black Coal Mine

Rock Coal Mine

Stockman Coal Mine

Tohora Stm.

Purupuru Stm.

Mohakatino River

Awahaehae Stm.

Rapanui Stm.

Mangahutiwai Stm.

Tongaporutu Village

Tongaporutu

WHITE CLIFFS

Tongaporutu R.

PUKEARUHE

Urenui R.

Urenui

WAITARA

NEW PLYMOUTH

Sugar Loaf Islands

Moturoa

Edge of Tapuae-Manganui Ridge

Boundary of New Plymouth Subdivision

OAKURA

KORU

AHUAHU

KAITAKI HILLS 2240 Ft.

Timaru

Oakura R.

Waiwakaiho R.

Hangaroa

Ngatoro

Ngatoro-iti

Waitepuke

Mangamahoe

Waiteika

Mangaiti R.

Manganui R.

Te Popo Stm.

Mangamoaka Stm.

TARATA

MIDHURST

WAIRUKU

KURAPETE

EGMONT VILLAGE

STRATFORD

Mud volcano of 1859

POUAKAI RANGE 4590 Ft.

MOUNT EGMONT 8260 Ft.

NOTE.
No attempt is made to define boundaries between series south of this. From reports by other investigators geological formations are as shown.

— Reference to Geological Colours and Signs —

TRIAS-JURA	Greywackes and argillites	
MIOCENE	*Onairo Series.* Claystones, sandstones, and conglomerates exposed at surface or very thinly covered with volcanic debris.	
	Exposed in valleys but overlain by considerable thickness of volcanic debris.	
UPPER MIOCENE AND PLIOCENE	*Pouakai Series.* Intermediate volcanic agglomerates, breccias, tuffs, and flows.	
PLEISTOCENE & RECENT	Gravels, sands, and muds	

Outcrops with observed strike and dip
" " no " " "

Compiled from data obtained from the Lands and Survey Department.
Geology by E. de C. Clarke and from maps by earlier investigators

Compiled and drawn by G.E. Harris & W. Bardsley. July 1911.

By Authority: John Mackay, Government Printer.

To accompany Bulletin No 14, New Plymouth Subdivision, Taranaki Division and Land District.

TASMAN SEA

WAITARA

MAMI

Mimi River

Urenui River

Urenui River

WAITARA

PATEA

WAITARA

UPPER

HUIRANGI

GEOLOGICAL MAP OF
WAITARA SURVEY DISTRICT

Compiled from data obtained from the Lands and Survey Department. Geology by E. de C. Clarke.

P. G. MORGAN
DIRECTOR

— Reference —

Roads ---------- shown thus
Trigonometrical Stations ,, ,, C 1841'
Swamp ,, ,,
Railways ,, ,,
Oil seepages (reported) ,, ,,
Gas vents ,, ,,
" " (reported) ,, ,,

— Scale of Chains —

80 40 0 10 160

— Reference to Geological Colours and Signs —

MIOCENE
- Onairo Series
  - Claystones, sandstones, and conglomerates exposed at surface or very thinly covered with volcanic debris
  - Exposed in valleys but overlain by considerable thickness of volcanic debris

UPPER MIOCENE AND PLIOCENE
- Pouakai Series
  - Intermediate volcanic agglomerates breccias, and tuffs
  - Contemporaneous peaty beds

PLEISTOCENE & RECENT
- Gravels, sands, and muds

Areas of local subsidence
Outcrops of boulders of Pouakai Series
" " finer debris " " "
" with observed strike and dip
" " no " " "

Compiled and drawn by G.E. Harris & W. Bardsley. June 1911.

By Authority: John Mackay, Government Printer.

P.G. MORGAN.
DIRECTOR

GEOLOGICAL MAP OF
PARITUTU
SURVEY DISTRICT

Scale of Chains
80 40 0 80 160

Reference

Roads ..... shown thus
Trigonometrical Stations ... " ... " ... C ◎ 1841'
Edges of Bush ..... " ... " ...
Swamp ..... " ... " ...
Railways ..... " ... " ...
Oil Wells - producing ... " ... " ... ●
" " drilling ... " ... " ... ⊕
" " Rig up or partially in position, but not operating or producing ... " ... " ... ⊙
Oil Wells - abandoned ... " ... " ... ✦
Oil seepages ..... " ... " ... ✕
" " - reported ... " ... " ... ✕
Gas vents ..... " ... " ... ●
" " - reported ... " ... " ... ●

Reference to Geological Colours and Signs

MIOCENE — Onairo Series: Masses of claystone interbedded with volcanic debris of Pouakai Series
UPPER MIOCENE AND PLIOCENE — Pouakai Series: Intermediate volcanic agglomerates, breccias, tuffs and flows
PLEISTOCENE & RECENT — Gravels, sands, and muds

Areas of local subsidence
Outcrops of boulders of Pouakai Series
" " finer debris " " "
" with no observed strike and dip
Lava flows

Compiled from data obtained from the Lands and Survey Department
Geology by E. de C. Clarke.

Compiled and drawn by G K. Harris and W Bardsley, June 1911

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NEW PLYMOUTH SUBDIVISION, TARANAKI DIVISION.

DE COURCY CLARKE.