SESSION II.

1921.

NEW ZEALAND.

MINES DEPARTMENT:

GEOLOGICAL SURVEY BRANCH

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

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

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LETTER OF TRANSMITTAL.

SIR,— Geological Survey Office, Wellington, 30th July, 1921.

I have the honour to transmit herewith the fifteenth annual report of the Geological Survey Branch of the Mines Department. This report covers the work of the Geological Survey during the twelve months that ended 31st May, 1921. Various special reports, most of which have been abbreviated for publication, are appended.

I have, &c.,

P. G. MORGAN,

Director, New Zealand Geological Survey.

The Hon. G. J. Anderson, Minister of Mines, Wellington.

DIRECTOR'S REPORT.

SUMMARY OF FIELD OPERATIONS.

DURING the past field season detailed topographical and geological surveys have been conducted in the following districts:—

(1.) Huntly-Kawhia-Hamilton district (Huntly-Kawhia Subdivision), under Dr. J. Henderson, Mining Geologist.

(2.) Whangarei - Bay of Islands district (Whangarei Subdivision), under Mr. H. T. Ferrar, M.A., F.G.S., Geologist.

(3.) Arowhana-Tokomaru district, north of Gisborne (Tokomaru Subdivision), under Mr. M. Ongley, M.A., B.Sc., Assistant Geologist.

(4.) Tahora-Tangarakau-Ohura district (Tangarakau Subdivision), under Messrs. H. A. Ellis and H. M. Marshall, temporary officers.

Brief visits for various purposes were made by the Director to the following districts: Greymouth, Reefton, New Plymouth, Picton, Taimate (near Ward), Dannevirke, Waipatiki, Tangarakau (two visits), Palmerston North, Mangahao, Glenhope (Nelson), and Alexander River (Reefton district). Dr. J. Henderson made two special visits to the Arapuni Gorge (Waikato River) in order to inspect the dam-site proposed in connection with important hydro-electric works; he also visited the Talisman Gold-mine (Karangahake), Aratiatia Rapids, and Marakopa (Awakino County). Mr. H. T. Ferrar inspected a low-grade oil-shale deposit near Mangonui, North Auckland; and Mr. J. Marwick (Assistant Geologist) visited the Oamaru district in order to examine possible sources of stone for harbour-works.

PROGRESS OF AREAL SURVEY.

During the twelve months ended 31st May, 1921, an area of approximately 2,465 square miles was geologically surveyed in detail. Of this area 1,034 square miles was in the Kawhia-Huntly Subdivision, 754 square miles in the Whangarei Subdivision, 366 square miles in the Tokomaru Subdivision, and 311 square miles in the Tangarakau Subdivision. The following table gives the present state of the detailed areal survey, which was begun in 1905 under the direction of Dr. J. M. Bell:—

	Square Miles.
Surveys completed, and work published, on scale of 1 in. to the mile ..	8,803
Surveys completed, and work published, on scale of ½ in. to the mile ..	325
Surveys completed, but work not yet published	5,246
Surveys in progress—area actually surveyed	677
Total area surveyed	15,051
Area in which work is suspended (Heaphy)	293
Area resurveyed (Whatatutu)	312

HUNTLY-KAWHIA SUBDIVISION.

During the past field season Dr. J. Henderson, Mining Geologist, and Mr. L. I. Grange, Assistant Geologist, geologically mapped the whole of six survey districts, forming what was originally to be called the Kawhia Subdivision. Owing to the geology of this area being very similar to that of the adjoining Huntly Subdivision, briefly described in last year's annual report, it has been decided to amalgamate the two areas and to write one detailed report upon the combined subdivisions. The area to be described contains the towns or villages of Huntly, Raglan, Kawhia, Pirongia, Ngaruawahia, Morrinsville, Te Awamutu, and Hamilton, and includes portions of seven counties—namely, Waikato, Raglan, Kawhia, Waitomo, Waipa, Piako, and West Taupo.

Huntly, where coal has been mined for nearly fifty years, is the most important coal-mining centre in the North Island. The fireclay beds of this neighbourhood have also been worked for many years. Recently the extensive limestone deposits have received attention, and two small plants have been built to supply the demand for pulverized and calcined limestone.

Whangarei and Bay of Islands Subdivision.

Work in the Whangarei and Bay of Islands Subdivision has been conducted by Mr. H. T. Ferrar, Geologist, assisted by Mr. W. H. Cropp, A.O.S.M., Geological Assistant. The area surveyed during the past two seasons extends from some distance south of Whangarei to north of the Bay of Islands, and has as its principal centres of population Whangarei, Hikurangi, Kawakawa, and Russell. From an economic point of view the mineral resources of this area are important, though not spectacular, the precious metals being found only in small quantity. They include deposits of coal, limestone, clay, and ores of mercury, silver, and manganese.

As one consequence of the detailed survey it is believed that the stratigraphical succession in North Auckland, long a puzzle, has been correctly solved. This, combined with other data, has a very important bearing upon the areal extent of the coalfields, which are now found to be isolated areas of comparatively small extent. However disappointing this result may be, it enables those areas where coal-prospecting is advisable to be defined, and thus much useless expenditure in searching for coal in localities where it does not exist may be avoided. Incidentally, owing to the soils, except in swamp areas, being almost everywhere of types distinctly connected with the underlying rocks, the geological map, with slight modifications, may be considered to be a soil-map.

Tokomaru Subdivision.

The Tokomaru Subdivision lies immediately north of the Gisborne and Whatatutu subdivisions, described in Geological Survey Bulletin No. 21 (1920). It includes the survey districts of Hikurangi, Mata, Waipiro, Arowhana, Tutamoe, and Tokomaru, and will probably be extended northward to East Cape.

The chief reason for a geological survey is the possible presence of petroleum in commercial quantity. Many attempts, some by no means well directed, have been made to find oil in the Gisborne - East Cape district, and all, notwithstanding various favourable indications, have been unsuccessful. Geological survey will certainly increase the chances of success. During the past season Messrs. M. Ongley and E. O. Macpherson, Assistant Geologists, have examined almost the whole of Arowhana, Tutamoe, and Hikurangi survey districts.

Oil-indications, including oil-bearing rock, are numerous, the geological structures are fairly favourable, and rocks capable of carrying large amounts of oil (potential "oil-sands") form part of the strata. Hence, as shown in the interim report by Messrs. Ongley and Macpherson on later pages, the presence of petroleum in commercial quantity is probable. Lest the casual reader may think that this probability approaches a certainty, he may be warned that not more than one district in six which appear geologically favourable for petroleum-production becomes a producing oilfield. In the present case, as is insisted on in the report, much field and other work has yet to be done before a final opinion upon its oil possibilities can be given.

Tangarakau Subdivision.

The presence of coal in the Tangarakau district has been known for many years, and from time to time favourable reports concerning the quality and thickness of the seams have appeared in the newspaper press. Last winter, owing to the shortage of coal in Taranaki, numerous requests for a geological examination of the Tangarakau Valley were made to the Government. Here, it was thought, a coal-mine not far from the rail-head at Tahora might be developed. Consequently it was decided to make a detailed geological survey of the district. A preliminary visit by myself to the Tangarakau Gorge, made last October, did not reveal much of promise, but in November Messrs. H. A. Ellis, Geological Assistant, and H. M. Marshall, Topographical Assistant, began field-work under my direction. The coal-bearing area was found to be of a very rugged character, and topographically to be very imperfectly mapped. Messrs. Ellis and Marshall, when field-work ceased, had mapped a wide belt of country extending from Kohuratahi to north of Ohura. This area contains numerous coal-outcrops, many of which were located for the first time during the course of the survey. The coal-seams, however, are thin, variable, and in places much affected by faulting. The thickest outcrops seen, one on the east side of Tangarakau Gorge, and another four and a half miles north-west of Ohura, measured 5 ft. North-west of Ohura the main seam, as it approaches the workable Waitewhena area, shows signs of thickening. As mentioned also on page 11, bands of conglomerate suitable for roadmaking purposes have been found in various places.

Palæontological Work.

During the past year Mr. John Marwick, M.A., Assistant Geologist, has been engaged mainly on the examination of the Tertiary Mollusca in the Geological Survey collections. Special attention has been given to the identification of the fossils collected during the past two field seasons by officers engaged in detailed surveys, and this work has been of great assistance in elucidating various doubtful points.

Several reports dealing with Tertiary, Cretaceous, and Mesozoic fossils have lately been received from specialists in other countries, and these, it is hoped, will soon be published. Mr. Frederick Chapman, A.L.S., F.Z.S., of the National Museum, Melbourne, reports that he has made considerable progress in his memoir on the collections of Foraminifera and Ostracoda sent to him some time ago. This work is a labour of love, performed entirely in the spare time of a busy man.

Publications.

The only publications actually issued by the Geological Survey during the year under review were the Fourteenth Annual Report and Bulletin No. 21, entitled "The Geology of the Gisborne and

Whatatutu Subdivisions, Raukumara Division," by Dr. J. Henderson and Mr. M. Ongley. In addition the following papers and reports by officers of the Survey were published in the *New Zealand Journal of Science and Technology* :—

" Avoca or Whatarama District—Mount Torlesse Collieries, &c." (Vol. 3, No. 3.) By P. G. Morgan.

" Geological Features disclosed by Excavations at the Proposed Dam-site at Arapuni, Waikato River." (Vol. 3, No. 4.) By J. Henderson.

" Tangarakau Coalfield, North Taranaki." (Vol. 3, Nos. 5 and 6.) By P. G. Morgan.

" Reefton Coalfield." (Vol. 4, No. 1.) By J. Henderson.

" Notes to accompany a Geological Map of the Cheviot District." (Vol. 4, No. 1.) By J. Henderson.

Since the end of the year Palæontological Bulletin No. 8, " Lists of New Zealand Tertiary Mollusca," by the late Mr. Henry Suter, has been issued. This bulletin, in addition to Mr. Suter's lists, contains notes and a review of results by Mr. P. G. Morgan.

Office-work, etc.

The office-work performed during the year has been of the usual character ; a large amount of correspondence has been attended to, and numerous requests for information on matters more or less connected with the work of the Survey have been answered. Several samples of rock to be used in roadmaking or for other purposes have been identified for the Public Works Department. Samples of several clays of good quality have been received and forwarded to the Dominion Laboratory for analysis. Samples of drillings from the Blenheim oil-bore, New Plymouth, at depths exceeding 5,500 ft. have been carefully examined ; these were mainly sandy claystones, containing petroleum in small quantity. The occurrence of petroleum-bearing strata in the New Plymouth district at so great a depth is a matter of much importance. Some of the drillings consisted largely of magnetic oxide of iron (ironsand), which was low in titanium content, and therefore essentially different from the modern ironsands of the present coast-line.

Samples of ochre and wad (hydrated manganese oxide) of splendid quality for paint-making purposes were received from a resident of New Plymouth. These came from the neighbourhood of Puketiti Hill, Carrington Road, between the Kaitaki and Pouakai ranges. Ochres of good quality were also received from Omakau (Central Otago) and from the Waihou district, near Te Aroha. A sand (artificially concentrated) from a spot a mile and a half inland from Purakanui Bay (Catlin's district) was of a very interesting character. It contained much zircon and a small percentage of rare earths (mainly ceria) ; other constituents were magnetite, ilmenite, a little chromite (chromic oxide 0·2 per cent.), and gold (10 dwt. 2 gr. per ton). Platinum, which was reported by the sender to be present, was not detected by the Dominion Laboratory, but the presence of chromite points to its probable occurrence in portions of the drift from which the sand was derived. Other mineral specimens received include polishing-earths from Puhipuhi and Wairakei, sharpening-stone (greywacke) from Waihao (per the Under-Secretary, Mines Department), barite from Rawene (Hokianga district), &c.

The Geological Survey is indebted to the Dominion Laboratory for the chemical examination of most of the more important mineral samples sent to the Geological Survey or collected by its officers. The analyses need not be given here, as they will be published in the annual report of the Laboratory.

Maps, &c.—During the year Mr. G. E. Harris, draughtsman, drew eight maps to be reproduced by photo-lithography, and ten others were partly drawn. He also prepared fifteen drawings for blocks, twenty-seven large field sheets for the use of officers in the field, and 110 miscellaneous drawings and tracings.

Library.

During the year numerous publications were received in exchange for Geological Survey bulletins, and a few books, mostly relating to economic geology, were acquired by purchase. The library now numbers about six thousand volumes, in addition to a large number of pamphlets and duplicates. It is invaluable for reference purposes to the members of the staff, and books from it have been lent to a number of persons who are either members of other Government Departments or are scientists of standing.

Objects of Geological Survey.

The preparation of geological maps and of geological reports describing the areas mapped form the primary work of a Geological Survey. Such work, however, is not to be regarded as the end to be achieved, but as a means for reaching other objectives, which in the final analysis are of utilitarian character.

The chief object kept in view by the New Zealand Geological Survey is the development of the mineral resources of the Dominion, not by itself setting out to discover and work mineral deposits, but by giving needful information (1) to prospectors, (2) to miners, and (3) to manufacturers and others who use mineral substances or products in their business. In part this information has immediate value, in part its value depends upon future work or research of some kind. The point needing emphasis is that most of the information required is not recorded in books or in the minds of men : it has to be sought for in the book of nature. Geological maps and descriptions serve mainly as an indispensable basis for geological research.

The Geological Survey by its investigation of natural resources is of use to many persons other than those mentioned above. It helps the agriculturist, the timber-miller, the civil engineer, the harbour engineer, the hydro-electric engineer, the builder, the roadmaker, and many others. By its publications it also helps the teachers of geology, who are endeavouring to train the next generation of geologists to do better and more useful work than has been done in the past.

SPECIAL REPORTS.

1. KAWHIA SUBDIVISION.

(By J. Henderson and L. I. Grange.)

Introduction.

Field-work began in the Kawhia Subdivision in October, 1920, and continued till towards the end of May, 1921. The subdivision as a whole is well roaded, is for the most part cleared of forest, and is largely lowland. These factors, combined with a favourable season, allowed the writers to examine a large extent of country; this included the survey districts of Karioi, Alexandra, Hamilton, Albatross, Kawhia North, Pirongia, and Puniu—in all, an area of 879 square miles.

Physiography and Structure.

The district is rectangular in shape, with its long sides (thirty-seven miles) extending east and west and its short sides (twenty-five miles) north and south. The western half of this area consists of a broad but much dissected plateau, and the eastern forms part of the lowlands of the Waikato basin. Immediately east of these lowlands is a wide belt of hilly country that southward rises to form the Rangitoto Range. The uplands, east and west, rise abruptly from the lowlands, and in plan are separated from them by straight or gently curved lines. The low country in fact lies between earth-blocks, from which it is separated by zones of fracture.

The plateau-like uplands and the volcanic cones that rise from them have been profoundly modified by erosion. Though much distorted and in part smothered with volcanic débris, the uplifted area has a general westward slope. Hence the greater part is drained by westward-flowing streams, which, though of moderate size only, are deeply incised almost to their sources in the plateau. The eastern side of the uplands is drained by streams that join the Waipa River. This large tributary of the Waikato rises among the eastern uplands and flows through the Kawhia Subdivision along the eastern edge of the central depression. The Waikato crosses the north-eastern corner of the subdivision, but receives little direct drainage from it.

General Geology.

Different parts of the subdivision have already been examined by Hochstetter, Cox, McKay, and Park; and in this brief account little can be added to their remarks. The oldest rocks, of Mesozoic age, were folded and eroded before the overlying Tertiary beds were deposited. The volcanic rocks that next succeed belong to three distinct periods of eruption. Gravels, raised-beach deposits, sand-dunes, and estuarine silts are accumulations of still later date.

The Mesozoic rocks range from the Upper Trias (*Pseudomonotis* beds) to strata that are probably of early Cretaceous age. An excellent section of all but the upper portion of the sequence is exposed along the south side of Kawhia Harbour and the adjacent coast west to Albatross Point. From this locality the Mesozoic strata are exposed along the southern boundary of the subdivision—in the western uplands as a narrow irregular strip, and across the depressed area in isolated patches. Mesozoic rocks also appear on the surface over the greater part of the western uplands north of the Kawhia rift-valley.

The Mesozoic rocks were folded, elevated, and the land formed thereby reduced to a surface of low relief by long-continued subaerial denudation before the deposition of the first members of the Tertiary sequence. These younger rocks, though much broken by faulting, usually lie flat or dip at small angles. They occur on or near the flanks of the western uplands as patches on down-warped or down-faulted blocks, although south of Mount Pirongia remnants on the crest of the ridges are still undenuded.

The lowest Tertiary beds consist of grits, sandstones, and mudstones, with coal-seams, and represent the estuarine and littoral deposits of a slowly sinking land. Over large areas these beds are absent—either they did not accumulate or they were removed by the waves as the sea transgressed on the land. The oldest purely marine Tertiary rocks are calcareous sandy claystones that in places reach a thickness of 80 ft., and in some localities are richly foraminiferal. They are overlain concordantly by the thick beds of limestone that form the most characteristic rock of the series.

The coarse-grained andesite that intrudes the Mesozoic strata near Albatross Point is not known to be connected with surface flows or fragmental material. It closely resembles, and is thought to be genetically related to, the rock that forms Moeatoa and Whareorino, twenty miles south of Kawhia Harbour. These mountains are the remains of volcanoes active between the Oamaruian and Wanganuian periods.

Pirongia, Karioi, Kakepuku, and the numerous smaller cones are decidedly younger than Moeatoa and Whareorino, having been formed toward the close of the Wanganuian. The earth-stresses that produced the block-faulting and differential movements of this period were also in part relieved by the extrusion of igneous rock. The principal centres of eruption, Mounts Pirongia and Karioi, consist for the most part of alternations of fragmental and flow rocks. There are numerous small scoria cones between Raglan and Aotea harbours, which appear to be of slightly later date than Karioi and Pirongia, though they certainly belong to the same volcanic period. On the other hand, Kakepuku and Kawa, small cones in the Waipa lowlands, are thought to be contemporaneous with Pirongia.

Unconformably overlying the rocks already described are beds usually referred to the Pleistocene. A great thickness of vesicular rhyolitic fragmental material (" pumice "), for the most part evidently laid down in water, and ranging in grain from silt to fine conglomerate, occupies the lowlands. These deposits are undoubtedly derived from tuff and breccia ejected by volcanoes in the Taupo zone. Some of the beds in the south-east corner of the district may be of subaerial origin. The cross-bedded and wind-blown sands of the coastal region are considered to be of the same age. They contain much ironsand, and in places pumiceous material.

The Recent deposits of the district consist of beach-sands, harbour-muds, fluviatile and marine gravels, and, most important of all, the water-borne pumiceous sands and silts of the Waikato Valley, together with the overlying peaty deposits.

Economic Geology.

The coal-measures of the district occur at the base of the Tertiary series, but over large areas are absent, and the overlying beds rest on the basal rock. Again, the Tertiary strata are much broken by faults and have been greatly eroded: thus the coal of the subdivision is confined to patches that are small when compared with the whole area examined. As stated in a former paragraph, the Tertiary patches occur most abundantly along either flank of the uplands, and only south of Mount Pirongia are small remnants of the Tertiary sheet left still undenuded on the crest of the range. Along the western flank of the uplifted mass coal-bearing strata are scantily present, and seams of workable thickness do not occur. On the other hand, along the eastern side patches of coal are found in a more or less continuous belt from the northern boundary to Mount Pirongia. Immediately north of the mountain is a large block of Tertiary strata, of which the base is nowhere exposed. East of the uplands south of Pirongia coal is again exposed. Westward, remnants of coal-measures on the crest of the southern uplands extend along the ridge-tops to the head of Kawhia Harbour. Outcrops of coal were examined at many points in this district, but although much coal still remains, the bulk of it has been removed by denudation. Northward, as the Kawhia depression is approached, the Tertiary beds are more continuous, and in this direction, as well as in the adjacent basins of the Okupata and Oparau streams, a large area of coal-bearing country may exist. The base of the Tertiaries, however, is below drainage level in this area, and much of it is concealed beneath volcanic breccia, so that the amount of coal it contains can be determined only by boring.

Refractory clays (fireclays) are found associated with the coal-seams only in small amount, and appear not to be of such good quality as those of the Huntly district. Massive claystones of Tertiary and Mesozoic age occur in vast quantity.

High-grade limestone occurs in the Tertiary beds at many points on or near the western uplands. A small plant which crushes limestone for agricultural purposes is situated at the foot of the uplands at a point sixteen miles by road south-west from Frankton. Large amounts of first-class limestone outcrop on the shores of Raglan and Kawhia harbours at points close to channels navigable by coastal steamers.

The beach and dune sands of the district, the latter occurring in large quantity, contain a considerable proportion of ironsand. In places wind and wave action have produced small deposits of almost pure blacksand. The average sand, no doubt, would yield a concentrate with a high iron-content.

Good roadmaking material is abundant throughout the western uplands. The hardest and most resistant rock is obtained from the basaltic flows and agglomerates and from some bands of greywacke.

In the lowlands good roadmaking material is scarce except near the southern border of the district. Some of the roads are formed of broken rock obtained from the Te Aroha or Te Kuiti districts. The grits and fine gravels deposited by the Waikato and Puniu rivers form an excellent surface, but a road made entirely of this material will not stand heavy traffic.

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2. WHANGAREI AND BAY OF ISLANDS SUBDIVISION.

(By H. T. Ferrar, Geologist, and W. H. Cropp, Assistant Geologist.)

Field-work and Area surveyed.

As shown by last year's report, the geological survey of the Whangarei and Bay of Islands Subdivision was still in progress in the month of May. This field-work was continued until the 9th July, when the winter rains rendered the roads impassable. The senior writer reassembled his party on the 30th September, and was continuously in the field until the end of May of this year. Mr. W. H. Cropp, A.O.S.M., joined the party as Assistant Geologist on the 23rd November.

During the past season the following survey districts were mapped in the order given: Kawakawa, Kerikeri, Whakarara, Bay of Islands, Russell, Whangaruru, and Purua, an area of some 608 square miles. In 1907–8 Dr. J. M. Bell and Mr. E. de C. Clarke made a systematic survey of the Whangaroa Subdivision, and the present survey has linked itself to their work along the eastern boundaries of the Whangaroa, Kaeo, and Omapere survey districts. Including the area mapped subsequent to the writing of last year's report, and portions of the Tangihua and Ruakaka survey districts on the shores of Whangarei Harbour, the total area surveyed during the calendar year was 754 square miles.

In addition a short excursion was made into the Waipu district in order to trace the relationship between the Whangarei coal-bearing series and the underlying formations. During December, 1920,

a week was occupied in travelling to and from Mangonui and reporting upon the occurrence of an oil-shale deposit in that area. The shales are of poor quality, and yield only 5 to 10 gallons of oil to the ton.

By comparing the cost per square mile of the survey last year with the cost this year it becomes evident that the work is accelerated and that economies are effected by having two geologists with one field party.

The chief object of the present survey is to determine the stratigraphical succession in order to make it possible to define (*a*) the known coal-bearing areas, and (*b*) the possible coal-bearing areas. Other objects of the survey are (*c*) to study the occurrences of minerals of economic value, and (*d*) to gather material relative to the productivity of the soils, and thus construct a soil-map of the district.

Summary of the Geology.

The stratigraphical succession of the late Mesozoic and of the Tertiary formations in the Whangarei and Bay of Islands Subdivision, and the relative positions of the coal-bearing horizons, were matters of some uncertainty until large areas of the country had been systematically mapped. The work of the past two field seasons has yielded a definite interpretation of the stratigraphy, has established the limits of the known coal-bearing areas, and has imposed certain limits upon the distribution of possible coal-bearing areas.

The geological history of the subdivision includes three complete cycles of depression, deposition, elevation, and erosion.

(1.) *The Waipapa Cycle.*—In Trias-Jura times a vast series of clays and sands of unknown thickness was laid down on the sinking edge of land of continental dimensions, which supplied the material so deposited. The continent finally disappeared; and following this the clays and sands were folded, crumpled, and indurated, and subsequently altered to quartzites, argillites, and greywackes. The folding was intense, and was accompanied by orogenic movements which uplifted these sediments until a new land-surface appeared. This land-surface was deeply dissected and maturely eroded before being depressed in Cretaceous times to such an extent that the greater part, or perhaps the whole, of what is now North Auckland sank beneath the sea.

(2.) *The Onerahi Cycle.* — During the Cretaceous depression claystones and impure limestones accumulated on the sea-floor in the present North Auckland area. Next in early Tertiary times the folding of the first-described cycle gave place to faulting accompanied by elevation and by the eruption of igneous rocks of intermediate composition. In places the soft Cretaceous strata were wholly removed by the denudation consequent on the uplift. After peneplanation the land once more began to sink.

(3.) *The Whangarei Cycle.* — On the edge of the sinking land, gravels, grits, and sands were deposited, and vegetable matter accumulated to a great thickness in some of the coastal lagoons and swamps. As the depression of this, the third or Whangarei cycle, continued the sea transgressed far over the land, but probably less extensively than during the Cretaceous. This further sinking allowed the accumulation of a series of calcareous sandstones and arenaceous limestones (shallow-water deposits). Renewed uplift subjected these sediments to erosion, which has continued to the present day. Those portions of the accumulated vegetable matter mentioned above, which survived the marine erosion during depression, were transformed to coal; the present coalfields of North Auckland represent those portions which have managed to survive the subaerial erosion of the final uplift.

Block-faulting, as well as the eruption of acidic tuffs and the extrusion of basic lavas, accompanied this final uplift, which gave the district its present topographical form. Since then, except for minor oscillations of level, this part of New Zealand appears to have been continuously above sea-level.

Age and Correlation of the Sedimentary Rocks.

The sediments accumulated in North Auckland at the beginning of the Waipapa cycle have yielded no internal evidence as to their age. This series is called the Waipapa Formation, and for several reasons, too lengthy to be detailed here, it is correlated with the Hokonuian (Trias-Jura) of other parts of New Zealand.

The Onerahi Formation, including the hydraulic limestone of Limestone Island, is often found resting unconformably upon the pre-Cretaceous land-surface. It has yielded a few imperfect fossils not sufficient to determine its age, but from the results of other workers it would seem that this formation accumulated during the Waiparan (Cretaceous) period.

The Whangarei Formation, including the crystalline or Whangarei limestone, rests upon the eroded surfaces of the Waipapa or the Onerahi Formation with marked unconformity. The assemblage of fossils—containing among others *Cucullæa alta, Dentalium solidum, Ostrea wuellerstorfi, Pecten williamsoni*, and *Turritella ambulacrum*—obtained from this formation places it in the Oamaruian (Miocene) system. Such forms as *Amphistegina* sp., *Pecten huttoni*, and *Pecten beethami*, found in the Whangarei limestone, prove that this rock belongs to the Ototaran stage.

Scattered outcrops of fresh-water leaf-beds containing fossilized leaves of living species of New Zealand trees, of gravels, and of carbonaceous sandstones, in part covered and preserved by sheets of basalt, give evidence of the existence of a Pliocene and Pleistocene land-surface.

Economic Geology.

As indicated in the report of last year, minerals of high commercial value are not abundant in North Auckland, but there are many accumulations of minerals of low value which could be utilized and thus be made commercially valuable. Deposits of coal, cinnabar, manganese, antimony, limestones, pottery clays, brick-earths, and glass-sands have been surveyed during the progress of the work; these are potential sources of wealth to the district.

Coal.—So far as present observations go, the coal in North Auckland is found in quantity only where the rocks of the Whangarei Series rest directly upon the older and more durable rocks of the Waipapa Formation. The coal-measures, however, have a sporadic development, and coal is absent in many localities where the two series occur in juxtaposition. No indications of coal have been found at the base of the Onerahi Formation, nor has it been found where the rocks of the Whangarei Series overlie the softer Onerahi strata. It would therefore seem that these facts, if generally applicable, will considerably simplify the search for coal. During the past year there has been a steady output of coal from the Hikurangi and Ngunguru coalfields, while the Whangarei coal-mine has recently been reopened. The seam recently laid bare at Kawakawa, in an area which was prospected by the late Bay of Islands Company, has been found less extensive than was at first anticipated. The coal-seam in the Waitangi Valley to the east of Waimate North is thin, impure, and of small area: it therefore seems to be valueless.

Other Minerals.—The cinnabar-mines at Puhipuhi are being developed but slowly. The antimony and manganese deposits of the subdivision have not been worked for a number of years. There is a steady output of hydraulic cement from Portland, in Whangarei Harbour, and an increasing demand for pulverized and calcined limestone for agricultural purposes.

Soils.—The geological map now in course of preparation is virtually a soil-survey, for each of the various formations encountered gives rise to a soil of fairly uniform lithological and chemical character. Research will tell us what agricultural treatment best suits the soil derived from each particular formation. When this is known the settler can be given precise directions as to the treatment of his land in order to reap the greatest profit. If the agriculturist finds he can just pay his way without external assistance, any advice which will enable him to increase the production of his farm will be profitable both to himself and to the State. Lastly, the published map will be of value to the settler, to the county authorities, and to the State, for it will show where hidden sources of roadmaking material may be located, and thus reduce the cost of road-construction and road-maintenance.

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3. PRELIMINARY REPORT ON THE TOKOMARU SUBDIVISION, WITH SPECIAL REFERENCE TO PETROLEUM PROSPECTS.

(By M. Ongley and E. O. Macpherson, Assistant Geologists.)

Introduction.

Before the white man came to New Zealand inflammable gas in the Gisborne – East Cape district was known to the Maoris, who gave to conspicuous vents the names Te Ahi-o-te-Atua and Te Hau-o-te-Atua. After the discovery and development of the Pennsylvanian oilfields, about 1860, Europeans became actively interested in these phenomena. More gas springs and oil-seepages were discovered; and from these occurrences, similar to those of known oilfields, people quickly concluded that here, too, was an oilfield. Several companies attempted to tap the "oil-pool" by digging pits and sinking bores near the seepages. Up to the present time the same method has been used. Gas and oil in small quantity have been obtained in several localities. The small production has disappointed those who thought they had only to make a hole near the seepage to get into the "oil-pool"; but, geologically considered, the obtaining of small quantities of oil and gas in such unfavourable localities as fault-pug zones is decidedly favourable. The operators, however, attempted to get oil without giving any heed to the geology at all; and at the present time the general geology of only a small part of the field is known, while no part has been done in the detail required in modern oil-work. But further haphazard ventures are not to be regarded as part of the systematic investigation of the field; for failures due to misguided effort have been taken, and are apt to be again taken, as indicating that there is no oil in the field. The steps in the work must be—first, geological examination and mapping of the whole possible oil-country, to mark out the more promising parts of the field; second, detailed examination and close mapping of the promising parts; third, structure-contour mapping and location of bore-sites; fourth, actual drilling.

Résumé of Field-work.

From November, 1920, to June, 1921, the writers were examining a part of the Gisborne – East Cape field, and covered the survey districts of Arowhana, Tutamoe, and Hikurangi, comprising some 470 square miles lying to the north of the area described in Bulletin No. 21. As a result of the work (1) indications more favourable than those previously known have been found, (2) the zones of petroliferous rocks have been demarcated, (3) some possible "oil-sands" have been located, and (4) in part the structure has been elucidated. Moreover, the sequence of the Cretaceous strata has been established.

1. *Oil-indications.*

The oil-indications given in Cunningham Craig's "Oil-finding" (pp. 143–83, 2nd edition, 1920) will be taken in order and discussed in relation to the East Coast field.

Seepages of Oil.—Within the Tokomaru Subdivision so far examined no seepage of oil is known; but at Waitangi Hill, which lies five miles to the south, oil with a paraffin base is escaping at the surface. Samples have been collected, but are not yet analysed. As pointed out by Craig, paraffin oil does not yield conspicuous seepages.

Asphalt Deposits.—In dealing with paraffin oil, asphalt deposits are not to be expected.

Evolution of Gas.—Regarding gas-shows Craig has written: "Though there may be steady and brisk flows of gas or gas-wells at a locality it does not necessarily prove that oil can be obtained by drilling there; but should the gas be heavy, with a fair percentage and a strong odour of hydrocarbons higher in the series than methane, the prospector will be justified in concluding that a body of liquid hydrocarbon is somewhere in the neighbourhood." By this standard the Tokomaru Subdivision of the East Coast ought to contain oil, for there is a belt of gas-shows, and the gas is "wet." As yet only one sample has been analysed; it shows 9·2 per cent. ethane. The gas from the others smells of petrol. Analyses recorded in Bulletin No. 21 show that out of seven samples collected in Gisborne Subdivision five are "wet" gas, containing 9 to 14·6 per cent. ethane. As a caution Craig states, "the evidence of a gas-show must be considered along with other facts, such as geological structure, if its value as an indication is to be appreciated correctly."

Outcrops of Bituminous Strata.—Craig has pointed out that paraffin oils do not afford good evidence in this respect, as they leave no residue. He wrote: "A faint odour of vaseline is often the only evidence that can be obtained." In the Tokomaru Subdivision rocks smelling of oil have been found in many places along a well-defined belt, and include fine dark shale, blue mudstone, calcareous concretions in blue mudstone, glauconitic greensand, grey sandstone, grit, and conglomerate.

Veins of Manjak or Ozokerite.—Ozokerite or mineral wax is the solid residue from the inspissation of paraffin oil beneath the surface. Within the Tokomaru Subdivision so far examined no ozokerite is known; but it is recorded that from Rotokautuku several tons of a substance which in part was possibly ozokerite were exported.*

Besides these important indications Craig discusses as of less significance the frequent occurrence of sulphuretted hydrogen and salt-water springs in oilfields. Many sulphuretted-hydrogen vents have been found in the Tokomaru Subdivision; and in the Gisborne – East Coast district many brine springs occur.

2. *Oil-zones.*

The dark shales above the blue mudstone in the Middle Cretaceous smell of benzine, but are not rich enough in carbonaceous compounds to burn. Within the area covered no oil or gas was seen coming from these beds; but at Rotokautuku, according to McKay, oil and gas were found in these rocks, and at Makarika gas is escaping from them. There are no sandstones or other porous rocks with these bituminous shales, and the oil-material is still in the shales.

The more prominent oil-zone is at the Cretaceous-Tertiary boundary, the gas generally coming from the Cretaceous beds, but in some cases coming through a thin cover of Tertiary strata. The oil-smelling beds include light-blue shale 50 ft. or more thick, dark shale 70 ft. thick, glauconitic greensandstone and grit 20 ft. thick, several bands of grey sandstone up to 20 ft. thick, and conglomerate up to 25 ft. thick. The oil in the more porous beds—the sandstones, grits, and conglomerates—has evidently migrated from its place of origin. These rocks have yet to be tested for porosity and suitability as reservoir rocks.

3. *Oil-sands.*

Traces of oil and gas in small quantity are found almost everywhere, but payable accumulations of oil are rare; and in any field it is necessary to find whether the oil has been concentrated into porous beds. Former observers have mentioned several beds as lithologically possible for reservoir beds in which the oil could accumulate; but no one has previously found definite evidence of oil in the sandstones, grits, and conglomerates of the Gisborne – East Cape district. The occurrence of oil in these coarser-grained rocks indicates that the oil has migrated. When the oil migrated it necessarily moved into the more porous rocks; and the movements would in large part be controlled by structure. Hence it is desirable to find oil-sands with suitable structure.

In the Tokomaru Subdivision possible oil-sands giving a smell of oil at the outcrop have been found in several places. At the lower oil-horizon there are no known porous beds associated with the dark bituminous shales. At the upper horizon in the Ihungia River a conglomerate more than 20 ft. thick has been found, in which the pebbles are generally about 1 in. diameter. None of these rocks has yet been tested for porosity; but there is only a little mud in the matrix of this conglomerate, and as it smells strongly of oil it is apparently an "oil-sand."† Near it occur several bands of fine grit and coarse greensand also smelling strongly of oil. These are friable and contain very little clay, and certainly will serve as oil-sands.

In the upper part of Makarika Stream and its tributary the Orua a brown sandstone enclosed in shale smells of oil. The sandstone appears to have a fair proportion of clay in the matrix, but it is more porous than the enclosing beds, and may serve as a reservoir for the oil. Another friable grey sandstone in the Mata River smells of oil, and from it oil has been extracted with chloroform. A greensandstone from the Mata also gives an oil-smell.

It is probable that other beds suitable as reservoir rocks occur, for the beds vary greatly from place to place, and outcrops in many places are separated by wide intervening stretches without outcrop.

4. *Structure.*

The most important information about any prospective oilfield is its geological structure, for, although oilfields have been developed without the structure being known, modern oilfield practice is

* According to W. Skey the material was dopplerite, an oxygenated hydrocarbon compound. See Trans. N.Z. Inst., vol. 14, pp. 397–99, 1882.

† Any rock which is capable of containing oil in quantity, and yielding it when tapped by a bore or otherwise, is technically an "oil-sand."

based on geological structure. In the Gisborne – East Cape field the structure has been several times investigated by geologists; and employees of the oil companies have endeavoured to locate suitable structures. As a whole the reports have been written on insufficient work and the structure elaborated on too little evidence. No work has yet been attempted in the detail required in modern oilfield examination. Although the survey of the Tokomaru Subdivision is far from complete, the general structure of a part of the possible oilfield can be indicated.

The rocks of the area examined can be easily subdivided into three groups, the topmost being the Tertiary, which gives no evidence of oil except where in close proximity to Cretaceous rocks, the lowest being the closely folded Lower Cretaceous which gives no oil-indications, and the middle being the possible oil-belt. The lowest part lying in the west and north is steeply folded and gives no evidence of oil. It is not greatly metamorphosed. In places it contains pieces of wood. These when analysed will give the "carbon ratio," and show whether the beds are too altered to be likely to retain oil. They are closely folded, and strike approximately magnetic north. No bed is distinctive enough to be followed, and therefore the folding cannot be traced in detail. The beds are steeply inclined, and in places are vertical. They dip constantly only for short distances, and in places dip in opposite directions several times within a chain.

The Tertiary beds lying to the east and south are unbroken, and, except near the Cretaceous contact, dip at a low angle—about 10°. The Cretaceous oil-rocks underlie; and in places in the Gisborne Subdivision pieces of them come to the surface through faults in the Tertiary. Oil in quantity may therefore be found below the Tertiary. Previously, from a study of Tertiary structure, sites were indicated for boring through the Tertiary to tap the underlying oil-rocks, but until the favourable sites in the Cretaceous rocks have been tested it is premature to talk of boring on Tertiary structure. It may well be that the Cretaceous rocks under the Tertiary are less disturbed and more favourable for oil-accumulation than where exposed at the surface, for as the rocks are progressively more distant from the steeply folded mountains in the west they are found to be less contorted. The folded oil-belt, however, should first be thoroughly investigated.

The belt containing the oil-smelling rocks runs from the south-west of the subdivision twenty miles north-eastward to the Mata–Waitahaia Junction, then eastward twenty miles to the coast. In the south-west it is some fourteen miles wide, at the Mata–Waitahaia Junction one mile and a half, and it widens to the east beyond the area mapped. The rocks of this belt are intricately folded. Moreover, they contain several patches of conglomerate with pebbles derived from the underlying beds, indicating erosion-surfaces not far away. The beds vary laterally and grade into others along the strike, and in many places the boundaries between any two beds is arbitrary, as there is no distinct lithological change. The structure of parts has been mapped; other parts remain yet to be mapped.

It has been well pointed out in the classification of petroleum and gas fields by Clapp* "that while geological structure is the most important factor in any examination for finding oil or gas, all the other factors must be given due weight in forming our conclusions; and, above all, we must use our judgment in digesting the field data. It is important, after finding the structure, to proceed in the following manner: (1) Make as accurate a structure-contour map as available data will permit; (2) with the help of 'convergence maps,' make a separate geological and well map for every individual sand; (3) before making any recommendations consider carefully the question of local peculiarities of the structure—water conditions, number, character, parallelism, and continuity of the sands, character of overlying beds, possible source of supply, metamorphism and 'structure habits' for the particular group of fields. By such an appraisal of the characteristics of the region it will not be difficult to form some conclusion of the probabilities of the prospective field."

Enough work has been done to indicate that the Gisborne – East Cape district probably contains an oilfield. It is not necessary here to enlarge on the present world-wide importance of oilfields; suffice it to say that the development of an oilfield in the Gisborne – East Cape district would make New Zealand the commercial and naval centre of the Pacific and give a great stimulus to the progress of the Dominion.

Urgent work remains yet to be done. The oil-belt must be followed and mapped wherever it appears. The more promising parts of the oil-belt must be mapped in greater detail. In particular it is necessary to "walk out" the structure and the boundaries in the complicated areas.

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4. TANGARAKAU COALFIELD, NORTH TARANAKI.

(By P. G. Morgan.)

The results of Messrs. H. A. Ellis and H. M. Marshall's field-work in the Tangarakau–Ohura district may be summarized as follows:—

A considerable area, extending from Tahora northward through the Tangarakau Gorge to north of Ohura, in Pouatu, Heao, Waro, and Ohura survey districts, has been geologically and topographically surveyed. Part of this area, notwithstanding its comparatively low altitude, is very rugged, and was unpleasant and difficult to survey. Dense forest added greatly to the difficulty of the work. Several quite large streams as well as many small ones, hitherto not on the Lands and Survey maps, have been surveyed, and it will now be possible to produce an excellent topographical map of the area examined.

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* F. G. Clapp: "Revision of the Structural Classification of Petroleum and Natural-gas Fields." Bull. Geol. Soc. Am., vol. 28, pp. 553–74, 1917.

The area in which coal-measures occur has been exactly delimited; and numerous coal-outcrops, many hitherto unknown, have been located, and are shown in exact position on the field-maps. The coal-measures proper are about 100 ft. in thickness, and contain in most places several seams of coal. The thickest outcrops observed, however, were only 5 ft.; one of these occurs on Section 2, Block I, Ohura Survey District (Aitchison's farm). The seam, however, does not maintain this thickness, but along the strike thins to 1 ft. 3 in. in 10 chains, and on the dip to 3 ft. in 20 chains. On the east side of the Tangarakau Gorge there is also a 5 ft. outcrop, but this contains some shaly bands. The thickest outcrop of clean coal elsewhere in the gorge is 3 ft. 9 in. In places faulting is prominent.

It is quite certain that under present conditions the coal of the Tangarakau Gorge and that near Tatu and Ohura cannot be profitably worked on a large scale. Small mines to satisfy local requirements may possibly be established at some future time, but in view of the important field of coal near Waitewhena, north of Ohura, immediate action in this direction does not seem advisable.

In several places thick but variable bands of conglomerate suitable for roadmaking purposes have been found.

The Ohura County Council intends opening a quarry in Gorge Creek, three miles west of Ohura. Here the conglomerate is 100 ft. thick. Mr. Ellis, as a result of the geological examination of this locality, was able to indicate to the County Engineer a much better site for the quarry than that originally selected.

To sum up the economic results of the survey:—

(1.) A good topographical and geological map of the area examined can now be produced.

(2.) The area in which coal occurs has been defined, and the coal-outcrops have been exactly located.

(3.) Roadmaking material has been found.

PICTON COAL.

(By P. G. Morgan.)

Introduction.

From the 23rd August, 1920, until the 28th, with the exception of the 25th, I was at Picton examining the coal-measures and other rocks of the district. On the evening of the 23rd, after my arrival at Picton, I was interviewed by members of the Chamber of Commerce. On the 24th, guided by Messrs. Thomas Allport and Walter Webster, members of the Picton Coal-prospecting Company, I visited Shakespeare Bay, Mount Pleasant, and other localities. From the 26th to the 28th I examined the whole of the environs of Picton.

Largely on account of coal having been discovered near Picton many years ago, the district has been frequently examined and reported upon by geologists. All the reports were adverse to the prospect of such coal as does occur being worked at a profit. My recent investigations, as might be expected, lead me to the same conclusion. In the hope that those interested will be able to understand the evidence which has caused several geologists, as the result of examinations widely separated in time, to form one and the same conclusion I will give a summary of all previous reports, and will give full reasons for my conclusions.

In 1864 Sir James Hector (then Dr. Hector) visited Picton, and observed indications of coal-measures being present. (Rep. Geol. Explor. during 1874–76, No. 9, p. 33, 1877.) Coal was discovered at Shakespeare Bay in May, 1874, and immediately thereafter Mr. Alexander McKay was despatched to Picton in order to examine the find. In a report which lacks detail McKay mentions "marls containing nests of coal, sometimes traceable as thin irregular seams for a few yards." These occurred on the east side of Shakespeare Bay. On the west side of the bay he noted rolled fragments of coal amongst the shingle on the beach. At The Elevation he saw "recent accumulations" of reddish gravel and clay, containing thin beds of carbonaceous matter and some remains of trees. Finding that "there was little probability of coal being got in paying quantities," he returned to Wellington. (Rep. Geol. Explor. during 1874–76, No. 9, pp. 32–35, 1877.)

In October, 1878, McKay again visited Picton, and reported in more detail concerning the coal than the year before. He states, however, that no discoveries of greater value than those he had previously inspected had been made, and his unfavourable opinion of 1877 was therefore fully borne out. Coal, he writes, was first found below high-water mark on the east side of Shakespeare Bay, where it occurred as a small seam not more than 3 in. or 4 in. thick. As a seam this continued for but a few feet along the strike of the rocks, and, followed downwards, became little more than a parting, separating the beds between which it occurred. A little to the north-east a shaft was sunk under the direction of Mr. Pugh to a depth of 27 ft. From the bottom a drift was made in a westerly direction for 12 ft., and a winze sunk from this to a depth of 6 ft., but apparently no coal was found. A new shaft-site was then selected on the foreshore a few feet to the west of the outcrop of coal first discovered. At 10 ft. a seam of coal 2 in. thick was encountered. This dipped to the westward at an angle of 45°, but, according to Mr. Pugh, when followed, first assumed a vertical dip, and then, turning over, dipped to the south-east at low angles.

McKay further states that thin irregular outcrops of coal were found on the western side of the valley at the head of Shakespeare Bay, and a shaft was sunk on one of these to a considerable depth, cutting a small seam 4 in. or 5 in. thick. In this shaft the strata were found to dip very steeply to the westward, and apparently passed under the schists, an outcrop of which showed within a chain

or so in that direction. A fault, probably reversed, therefore separates the coal-measures from the schists. Towards the end of his report McKay repeats his unfavourable opinion of 1887, to the effect that there is little probability of coal being found in payable quantities. (Rep. Geol. Explor. during 1878–79, No. 12, pp. 86–97, 1879.)

About the beginning of September, 1880, McKay again visited Shakespeare Bay and examined a coal-seam lately discovered on the west side of the valley at the head of the bay about 15 chains from the shore-line. The beds in which the coal occurred were observed to dip at very high angles, and near the coal-seam were striking north-north-east. Mr. Renfrew, who was in charge of the prospecting, stated that where laid bare at the surface the coal was 14 ft. thick. At the date of McKay's visit the shaft was 40 ft. deep, and coal showed from top to bottom in such a way as to convince him that the seam was more than 6 ft. thick. Near the shaft a prospecting-drift followed the coal for a short distance to the south-south-west. The seam was then lost (by faulting) or turned sharply to the east. As the drift had collapsed, McKay was not able to examine it. While admitting that a certain amount of coal could be obtained from the comparatively thick seam lately discovered, McKay concludes his report with a statement implying that there was little possibility of workable coal being found in quantity. (Rep. Geol. Explor. during 1879–80, No. 13, pp. 147–49, 1881.)

In 1881 a thick outcrop of coal was discovered on the eastern side of the Shakespeare Bay valley. In his progress report of 1882 Sir James Hector remarks that both he and Mr. McKay have frequently visited Picton, and every important step made in exploring the coal has been carefully observed. He gives sections along the east and west shores of Shakespeare Bay, showing that the coal-measures are much disturbed. The latest discovery is referred to as "Fell's coal." It had been explored, Hector states, by a short irregular excavation to a depth of 25 ft. The coal was from 6 ft. to 13 ft. in thickness. Attempts to trace it on the strike of the seam had not been very successful. Hector remarks on the good quality of the coal, and states that a considerable quantity could be profitably extracted by shallow workings. He says: "In this way, without much outlay of capital, a better knowledge of the deposits would be obtained, so that the proper method of opening up a mine could be decided upon, which is at present quite impossible." Finally, he stresses the necessity for extreme caution in projecting expensive shafts or other works. (Rep. Geol. Explor. during 1881, No. 14, pp. xiii–xvi, 1882.)

In August, 1881, McKay once more examined the Shakespeare Bay coal deposits, and as a result furnished a fairly exhaustive report, accompanied by two maps. (Last publication cited, pp. 106–15, and maps at end of volume.) He considered the discovery on the east side of the valley, close to the head of Shakespeare Bay ("Fell's coal"), to be important. At the surface the seam was 6 ft. thick, dipping very steeply to the east. At 25 ft. in a shaft sunk on its western side the seam was 13 ft. 6 in. thick, and according to Mr. Renfrew, manager for Mr. Fell, the lessee, existed for another 30 ft. down. To the north coal had been followed for 35 ft., but in that direction the coal thinned, and in the farthest point reached in a level had disappeared (? through faulting). The 25 ft. level from the shaft previously mentioned encountered, on its north side only, coal 15 ft. to 20 ft. west of the line of strike of the seam as observed at the surface. This was followed for 10 ft. to the north, but as the seam did not appear well defined the branch drift was discontinued, in McKay's opinion, prematurely. On the beach, north of Fell's outcrop, coal could not be detected. No attempt had been made to follow the coal to the south, but in that direction it would not live for more than 6 to 7 chains. McKay considered that about 9,000 cubic yards of coal was available for working at Fell's mine. Actually about 800 tons seem to have been extracted. The recorded output is 658 tons.

McKay states that on the west side of Shakespeare Bay a bore was put down to a depth of over 200 ft., limestone and traces of coal being found. A few yards to the south a shaft was sunk, and passed through coal dipping at a high angle to the eastward. According to information supplied to me by Messrs. Allport and Webster, this was probably McKenzie's shaft, which was 72 ft. deep. The coal, 6 ft. thick, was encountered in a short drift made from the bottom of the shaft. McKay also mentions an adit driven south-west and westward into the hill between the third and fourth branches of Laymont's Creek. This passed through greensands only. In the fourth branch of the same creek coal was observed at a height of 325 ft. above sea-level, striking N. 15° E. Here the seam was 8 ft. or 9 ft. thick, but the coal was interstratified with shaly bands.

At the time of McKay's visit in 1881 work at Pugh's shaft, on the east shore of Shakespeare Bay (near the boardinghouse erected some years ago by the meat-freezing company), had been discontinued, and prospecting was being carried on under Mr. Pugh's direction along the northern boundary of the coal-measures (close to where the Picton Freezing-works now stand). An adit on the Shakespeare Bay side of the narrow neck of land had been driven for fully 200 ft., and coal followed for the latter half of that distance. The coal occurred in a most irregular manner, the seam here thinning to a few inches, there swelling to 2 ft. or 3 ft. in thickness, in one place lying horizontal, in another standing vertical, and so on. Evidently the strata were much disturbed by faulting. A few tons of coal had been obtained in prosecuting the work, but no defined seam or large body of coal had been found. An adit had also been driven on the east side of the narrow neck of land on which the freezing-works stand. This passed through dark marly shales containing carbonized plant-remains and a few thin streaks of coal.

McKay also mentions that previous to his visit some unsuccessful prospecting for coal had been carried on at The Elevation, one and a half miles south-south-west of Picton. His report concludes with a number of rather obscurely worded statements, from which it may be gathered that, although he did not wish to condemn further exploration, he was not at all favourably impressed with the prospects of the Picton coalfield. The last paragraph of the report, however, states that a few thousand tons of coal can be profitably won from the large seam (Fell's) being opened on the east side of Shakespeare Bay. This prophecy, unfortunately, was not found to be correct.

In 1894 Sir James Hector, in his progress report, refers at some length to the Picton coalfield. He states that a supposed new discovery was nothing more than the outcrops found and reported on in 1880, which occur south-west from Shakespeare Bay on the slope of the schist range. He concludes his remarks as follows: "It has been considered advisable to recapitulate what is known of the Picton coalfield, in order to put prospectors on their guard. There is no doubt that the composition of the coal is that of an excellent fuel for steam-generating, though rather tender and liable to form an excessive amount of dross; also that the locality, close to deep water in a splendid land-locked harbour, would give to a coal-mine so situated a vast importance; but ever since I first examined the locality I have doubted if there is any solid prospect of coal-seams being found that would support extensive mines. This opinion was based upon the fact that the presence of the coal-bearing rocks in the district was due to their being caught in between the sides of a great fault which marks the boundary-line between the foliated schists to the west and the old sandstone east and south of the Town of Picton. To this fact is due the very high angle at which the coal-bearing beds are found, the indurated condition of the beds, and the crushed character of the coal-seams. The denudation which has since taken place has removed the coal formation from each side of the fault-lines." (Rep. Geol. Explor. during 1892–93, No. 22, p. xxx–xxxiii, 1894.)

In August, 1914, I visited Picton, and reported as follows: "There is no chance whatever of coal being mined at a profit on a large scale either at Shakespeare Bay, The Elevation, or in the upper Tuamarina Valley—for example, at Mount Pleasant. The reason for this is that the coal-bearing areas are exceedingly small, whilst the coal present is dipping at high angles almost everywhere, is much faulted, irregular in thickness, . . . and variable in quality. It is possible that near Shakespeare Bay a few hundred tons of coal can be mined without loss for local use, but even this is very doubtful. A little surface prospecting may not be inadvisable. . . . Boring, shaft-sinking, or any expensive form of prospecting must be condemned as leading only to disappointment and loss of money, without any compensating advantage." (Ninth Ann. Rep. N.Z. Geol. Surv., part of Parl. Paper C.–2, pp. 81–83, 1915.)

During the early "eighties" of last century, while a serious attempt to mine coal at Picton was being made, the mine-workings were inspected several times by Messrs. S. H. Cox and G. J. Binns in their capacity as Inspectors of Mines. In 1883 Mr. Binns submitted brief reports upon the Picton Coal-mine (Fell's), Picton and Shakespeare Bay Coal-mine (Pugh's), and the Queen Charlotte Sound Coal-mine (south-west of The Elevation). The first of these concerns had sunk a shaft 55 ft., the second was driving a level but had not arrived at anything definite, and the third had found no coal. (Parl. Paper H.–11, p. 8, 1883.) Next year Mr. Cox described the workings of the Picton Coal-mine at some length. Two seams had been discovered, neither of which promised to be of any great extent. In character they were exceedingly patchy, the coal in several places being seen to pinch out from 4 ft. or 5 ft. to less than 1 ft. in the width of a drive; and in other places, though the thickness of the seam remained constant, coal at the top of the drive was represented by nothing but shale at the bottom. (Parl. Paper C.–5, pp. 18–19, 1884.) In 1885 Mr. Binns reported that the Picton Coal-mine was still working (during 1884), but doing very little. (Parl. Paper C.–4, p. 7, 1885.) In 1886 he reported that the mine had been idle during 1885.

The following table shows the production of coal from Picton mines as given in official statistics:—

——	Prior to 1880.	1881.	1882.	1883.	1884.	Total.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Picton and Shakespeare Bay Coal-mine ..	50	..	3	..	..	53
Picton Coal-mine	..	75	8	100	475	658

Messrs. W. Syms (owner) and John [? Thomas] Pugh are mentioned in the old Mines Reports as managers of the Picton and Shakespeare Bay Coal-mine; Messrs. R. R. Hutcheson, John Renfrew, and F. Coombe are recorded as managers in succession of the Picton Coal-mine. In the former mine the coal-seam is stated to dip at 40° to the north; in the latter mine two seams—one 5 ft. thick, the other 12 ft. thick—dipping vertically, are reported.

Recent Observations.

It will be helpful, I think, if I give my observations largely in the form of a narrative. On the 24th August, accompanied by Messrs. Allport and Webster, I went first to the old Picton Coal-mine (Fell's) on the eastern side of the head of Shakespeare Bay (Section 4, Block VII, Linkwater Survey District). Here there is nothing now to be seen except the old open-cut, whence coal was mined. This is, say, 40 ft. long, 20 ft. wide, and 10 ft. or so deep (dimensions very rough). At the north end shaly rock, dipping vertically and striking east of north, appears. The mine-dump shows coal, highly calcareous conglomerate, and calcareous fossiliferous claystone of a dark colour. The fossils indicate a Tertiary age. On the foreshore a few chains north and north-east of the mine the coal-measure rocks exposed are brown sandstone, fossiliferous conglomerate, and shale. These rocks strike north-east, and dip steeply to the north-west. From the Picton Coal-mine I proceeded to the west side of Shakespeare Bay. Here, along the shore (Kaipupu Scenic Reserve), the principal rock exposed is mica-schist, but for some chains a narrow band of shale, more or less carbonaceous and greatly crushed by faulting, shows at high-water mark. A few yards inland a shaft has been sunk by the Picton Coal-prospecting Syndicate 85 ft. in mica-schist. At the time of my visit this shaft was standing idle owing to difficulty with water. The intention of the Picton Syndicate was to drive eastward from the bottom of the shaft under Shakespeare Bay. No one with experience in coal-

mining could conscientiously recommend the sinking of a shaft in this locality, or indeed any kind of prospecting-work other than mere inspection of the ground. A short distance north of the shaft is an old adit driven from high-water mark for a short distance in mica-schist. If this adit was driven in search of coal it was a singularly ill-advised undertaking. According to an old manuscript map by Mr. Alexander McKay it was 66 ft. in length, with a borehole 40 ft. deep at the inner end.

Next a visit was paid to the prospecting-cuts near the head of Laymont Creek, at a point about a mile south-west of the shaft mentioned above. These cuts are about 400 ft. above sea-level; they show carbonaceous shale polished by fault-movement, some lighter-coloured shale, and thin irregular lenticular bands of coaly matter. These beds dip very steeply to the north of west. Superficially the dip is much flatter, owing to the creeping of the beds down the hillside. Prospecting here is justifiable, but so far the results have not been encouraging.

In the afternoon I went to Webster's old shaft, situated on Section 23 (probably), Block XII, Linkwater Survey District, about three-quarters of a mile south of the head of Laymont Creek, at a point about 400 ft. above sea-level. The shaft is said to have been sunk by Mr. Webster, sen., about twenty-five years ago. The dump consists of greywacke, much of which has been crushed by faulting. The shaft is stated to have passed through a 3 in. seam of coal. The greywacke undoubtedly belongs to a series of rocks much older than any of the proved coal-measures in New Zealand—namely, the great Trias-Jura system of this country, which in places contains thin unworkable seams of coal.

From Webster's shaft I went to an excavation made at a barometric height of 490 ft. on the right bank of a small stream a few chains to the westward or south-westward of the shaft. The rock here is bluish shattered greywacke, the joints of which show innumerable lustrous black surfaces polished (slickensided) by fault-movements. The rock is traversed by numerous minute white veins, probably of calcite. When scratched the black polished joint-surfaces yield a white or nearly white powder. There may be a trace of carbonaceous matter in the rock, but there is absolutely no indication of coal.

Still accompanied by Messrs. Allport and Webster, I next proceeded to a locality north-west of Mount Pleasant Railway-station (not far from Weston's). Here, on the saddle at the head of Speed's Valley (probably on Section 120, Block XI, Linkwater Survey District), is an old adit in schistose white-veined greywacke. The barometric height is about 370 ft. It is said that a small seam of coal was intersected in the adit. In a gully on the east side of the saddle is a prospecting cut and pit in brown schistose greywacke, which at the bottom of the pit is changing to a bluish colour. Concerning this locality Mr. G. J. Binns, Inspector of Mines, wrote in 1883: "Queen Charlotte Sound Coal-mine: This is another prospecting-drive, belonging to the Queen Charlotte Sound Coal-mining Company (Limited), of which Mr. R. Reeves is secretary. The site of present operations is on the other side of the saddle, west of Mr. Weston's house, and at my visit in December (1882) there was no coal, though a seam has, it is said, been found on the east side." At that time Mr. T. Adams was mine-manager. (Parl. Paper H.–11, p. 8, 1883.) On the hillside to the south of the prospecting-pit there are some hard boulders of conglomerate. This consists of pebbles, nearly all small, of argillite, greywacke, and perhaps other rocks, set in a fine groundmass. One boulder showed some fairly large quartzose and flinty pebbles, up to 2½ in. in diameter. A sample broken from one of the boulders did not show any effervescence with nitric acid, but a test with ammonium molybdate showed that it was slightly phosphatic. These boulders may have come from a bed of the same age as the conglomerate at Shakespeare Bay; on the other hand, they may be, as I believe they are, of much older age. In any case, there is no evidence whatever of the presence of workable coal at Mount Pleasant. The prospecting operations have been carried on in the Trias-Jura rocks, which are not known anywhere in New Zealand to contain workable coal-seams.

I also inspected the bed of the creek running north from The Elevation Railway-station. Here, a short distance north of the station, a band of dark-coloured shaly argillite, bordered by greywacke, outcrops. These rocks belong to the Trias-Jura series, and cannot be considered as possible coal-measures. Some masses of Tertiary limestone (not in place) are visible along the banks of the stream, and fault-involved coal-measures may possibly occur in a narrow band not far away.

Reported Coal-occurrences.

The 3 in. seam of coal in or near the shaft sunk by Mr. Webster, sen., many years ago has already been mentioned. In a gully west of the railway-station coal 18 in. thick is said to have been worked many years ago, and used for blacksmithing. On the other side of the valley (head of Tuamarina), south-west of the last-mentioned occurrence, lumps of carbonaceous shale with adhering coal of good quality have been found. A small lenticular seam of coal is said to have been found during the working of the quarry in the Trias-Jura rocks on the south side of The Elevation Railway-station.

North of Picton the track beside the baths exposes a small layer of dark shaly argillite, which appears to contain some carbonaceous matter. The outcrop is small, and much disturbed.

Although personally I saw nothing more than slightly carbonaceous bands in the Trias-Jura rocks of the Picton district, it is possible that, as in several other parts of New Zealand, they do contain small lenticular coal-seams of no value.* As the Trias-Jura rocks are everywhere highly inclined, any workable coal-seam they might contain must almost inevitably outcrop, and in that case would be easily detected by surface examinations. Only complicated faulting could altogether prevent the coal-seams from outcropping. In that case the seams would be so deep and so broken that they could not well be worked, even if their existence could be predicted. A very good reason for not searching for coal in the Trias-Jura rocks of New Zealand is that such rocks outcrop over great areas both in the North and South Islands, and, as already stated, are nowhere known to contain workable coal.

* See also references to graphite on a later page.

Sections illustrating Coal-measures, etc.

According to my notes of August, 1914, the Tertiary coal-measures may be seen in contact with Trias-Jura greywacke on the western shore of Picton Harbour, north-west of the end of the new wharf. For 11 chains or more to the north from the contact the Tertiary rocks are shelly conglomerate, pebbly limestone, and sandstone, more or less faulted for the first 2 chains. At 4½ chains to the north of the contact a 6 ft. band of sandstone strikes 321°, and dips at 65° to the south-west. At 5½ chains to 8 or 9 chains Trias-Jura greywacke seems to underlie the conglomerate. At 8 chains there is sandstone, striking 256° and dipping about 25° to the north-north-west; it rests on twisted greywacke. Hence an anticlinal structure seems to be present. From 9 chains to the point near the freezing company's wharf, where outcrops cease, the dip of the Tertiary beds steepens. North of the wharf the first rock visible is a crushed breccia formed of schistose rocks and greywacke. The predominating rock in this crush-zone is schist, with quartz laminæ; some phyllite is also present. The masses of schistose rock lie nearly flat.

On the western side of the peninsula, below the freezing-works, a brown sandstone which dips at 50° or 60° (probably) in an easterly direction is seen for several chains along the foreshore. It is succeeded southward by a fine dark-coloured conglomerate, which is perhaps of Trias-Jura age. Coarse brown sandstone and fine conglomerate, undoubtedly belonging to the Tertiary series, are next seen. A small excavation has lately been made in these rocks just above high-water mark. Not far from here the first discovery of coal in the Picton district is said to have been made, and in consequence the prospecting-shafts mentioned on an earlier page were sunk under the direction of Mr. Pugh. Conglomerate continues to outcrop for some chains to the south-west. A coarse breccia-conglomerate involved in a fault-zone is then seen for over a chain. Bands of argillite and fine-grained greywacke (Trias-Jura) just to the south strike 225°, and dip at 65° to the south-east. Half a chain on, the strike is nearly the same, but the dip is 90°. Then coarse sandstone, fine conglomerate, and coarse conglomerate appear in succession. The next rock is a narrow band of fault-crushed greywacke. This is followed by a shelly conglomerate, and this by shale and sandstone, striking 178°, and dipping at 45° to the west. The old workings of the Picton Coal-mine are a few chains to the south. Brown sandstone appears at intervals to the mouth of Williams Creek. It contains indistinct shell-casts, but no recognizable fossils. To the south-west a patch of the same rock outcrops on the roadside just to the east of Laymont Creek.

As will be gathered from the descriptions, the coal-measures as seen in section along the east and west shores of the neck of land on which the freezing-works stand are much contorted and faulted. Moreover, only thin irregular coal-seams have been discovered. Hence any further attempt to prospect the area must be regarded as altogether inadvisable.

Faulting.

Reference to faults has been made in preceding sections of this report.* The depressed belt or trough between Picton and Tuamarina has a complex inner structure. Each boundary fault is a fault-zone, and not a simple break. In addition the depressed area is badly smashed by subsidiary faults, some nearly parallel to the main faults, others nearly at right angles to them. Only near Picton has the subsidiary faulting been distinguished in any detail, as shown on the accompanying map, but even there much careful field-work and exact mapping on a large scale are required in order to attain anything like completeness.

The eastern main fault is indicated east of Waikawa Village by low spurs or shoulders, above which a steep high slope begins. The fault, evidently trending south-south-west, traverses the headwaters of the Waitohi Stream some distance above the Picton Reservoir. In the Koromiko district it is perhaps two miles east of the railway-line, but my observations do not enable me to say what is its position farther south, though if its direction remains unchanged it must approach the railway and the Tuamarina River valley.

The main western fault practically determines the western side of Shakespeare Bay. Thence it trends south-south-west towards Mount Freeth; but whether it turns more to the south so as to pass along the eastern base of Mount Freeth, or actually keeps on its course and intersects the mass of Mount Freeth, has not been determined. There is, however, a great fault at the eastern base of the mountain, in line with the fault which determines the vertical position of the coal at the old Picton Coal-mine. Probably the main western fault does turn a little to the east so as to join the subsidiary fault. It would not be surprising if a third fault, coming from Picton Bay, joins the other two here. In any case a great fault-zone continues south-westward from the foot of Mount Freeth, passing through Speed's Valley and Bragg Creek Valley, and finally reaching the Wairau Valley well to the west of Tuamarina. The fault as described forms the boundary between mica-schist of supposed Palæozoic age and less altered rocks of Trias-Jura age. Hence it may well be, in part, of pre-Tertiary age. The fact that the northern part of the peninsula between Picton and Shakespeare bays consists of schist may be construed as evidence of pre-Tertiary faulting. However this may be, the fact that Oamaruian strata are involved in the faulting proves a late Tertiary age for the fault as it is now revealed.

A fault passes along the western side of the broad low valley between Waikawa Village and Picton. It trends south-westward through Picton and past The Elevation, whence it continues for some miles down the eastern side of Tuamarina Valley not far from the railway-line. Evidence of it is afforded not only by the topography, but by the almost vertical Tertiary claystone seen in Waitohi Stream near the Picton power-house and at The Elevation. There may be a parallel fault about

* See also Sir James Hector's remarks of 1894, quoted on page 13 of this report, and Mr. Alexander McKay's various reports.

half a mile to the eastward. The rocks on the eastern side of Picton Harbour, near the baths, are disturbed by faulting, probably along nearly north-and-south lines.

The faults so far mentioned are nearly parallel to the trend of Picton Bay, Shakespeare Bay, and the upper part of the Tuamarina Valley. On the peninsula between Picton and Shakespeare bays a set of cross-faults is easily detected. The most northern of these, striking east-south-east, forms the boundary between the Tertiary strata and the mica-schist previously mentioned as forming the northern part of the peninsula. It is probably a reversed fault. A nearly parallel fault, but having its downthrow to the north-east and striking almost south-east, forms the southern boundary of the patch of Tertiary strata in this locality. A third fault a little to the south of the last is almost or quite parallel to it. These cross-faults to the north-west pass under the waters of Shakespeare Bay, and probably end at the main westerly fault. Whether they affect the rocks east of Picton Bay has not yet been determined.

The Picton–Tuamarina fault-trough contains several moderately low ridges which have nearly flat crests, meeting the higher slopes at an angle, similar to that formed by the bottom of a cutting with its sides. This feature not only indicates faulting, but an ancient plane of erosion, formed when the land stood lower than it is now or when the land had much greater extent seaward. The fault-trough also contains several detached or semi-detached hills, such as that at The Elevation, a feature that in itself is usually indicative of faulting.

Prospecting-principles.

Why have the people of Picton, in spite of much discouragement from geologists and others, continued to prospect the coal-measures of the district? An answer may perhaps be given as follows:—

From time to time unexpected discoveries of coal have been made, and each new discovery has naturally raised fresh hopes. The coal occurs close to one of the best harbours in the world, and if Providence had only been so kind as to supply a coalfield to fit the shipping-facilities Picton would have become by this time the Newcastle of New Zealand, altogether free from the troubles that have harassed the Greymouth and Westport Harbour Boards. I take it that the good people of Picton could not help reasoning that so fine a harbour ought, in the fitness of things, to have a good coalfield attached to it, and that search for coal was therefore thoroughly justified. It is possible also that the conditions of life at Picton are such as to induce an invincible optimism. One other cause —probably the principal cause—of the renewal of prospecting from time to time was the fact that nearly all concerned had little or no knowledge of coal-mining or geology. The various attempts to develop coal-mines have, in truth, been instances of "the valour of ignorance." I shall now endeavour to point out some of the mistakes made owing to want of knowledge and experience, so that any future prospectors may be able to avoid, in part at least, the errors of the past.

It is a great mistake to suppose that a thin outcrop of coal a few inches thick is worth following underground, either by driving or sinking, in the expectation that it will increase in thickness till it becomes workable. Such an outcrop may be worth following on the surface. It may, in the course of a quarter of a mile, thicken to a workable seam; more likely it will thin out altogether. If it cannot be followed on the surface the proper course is to look for a thick seam above or below the thin seam, or wherever the coal-bearing rocks can be found outcropping. As a rule under New Zealand conditions not much trenching will be necessary. If thick coal-outcrops exist they will probably be detected in stream-beds or on the face of cliffs. If no workable coal can be found outcropping, then, as a rule, prospecting should be abandoned. In certain cases, if a competent geologist or a highly experienced mining engineer so advises, boring may be undertaken at selected spots.

Great caution should be exercised where the coal-measures are much disturbed by faulting. It is an axiom among New Zealand mine-managers that coal standing on end (dipping very steeply) cannot be profitably worked. In view of the present high price of coal this opinion perhaps requires a little qualification, but at Picton the coal-measures are so highly disturbed and broken that the axiom holds good.

In order to make a coalfield there must be a considerable area underlain by coal: this is not the case at Picton. The coal-seams must be fairly regular in thickness and quality: this is not the case at Picton. In the Picton Coal-mine, for instance, the seams thinned capriciously in the drifts, and varied in composition from coal to carbonaceous shale in the course of a few feet. This might be put the other way: in some places the seams greatly thickened in the course of a few feet, and in other places changed just as rapidly from shale to good burnable coal; nevertheless, the same unfavourable conclusion may be drawn. A seam that changes in a few feet from bad to good will probably—nay, certainly—change from good to bad in a short distance. Such variability is fatal to economical mining.

Though not a logical necessity, it is in a way desirable that the stratigraphical sequence of a new coalfield should be the same as or similar to that of an established coalfield; this is not the case at Picton. No strongly marked resemblance between the strata here and those of the Westport, or Greymouth, or other important New Zealand coalfields can be traced. To be sure, there is some similarity, but the differences are greater. As a rule, only a competent geologist or a mining engineer of good judgment and experience can draw reliable conclusions from rock-characteristics.

From time to time various persons have stated that limestone and sandstone are "indications" of coal. This is a fallacious mode of reasoning. In nearly all coalfields of importance one finds, besides coal, such common rocks as shale, sandstone, limestone, &c. It is not logical, however, to reason that the occurrence of any one of these rocks shows that coal is present; for there are vast

areas without coal, but possessing abundant deposits of shale, sandstone, limestone, &c. It would be more logical to consider the presence of coal proof of the presence of shale and sandstone. A very common fallacy among coal-miners is to suppose that a dark-coloured clay, or even a light-coloured clay, is evidence of the presence of coal. The clay, without proof of its refractory nature, as a preliminary begging of the question, is called "fireclay," which in most cases it is not. Ordinary clay is no indication of the presence of coal. Even if the clay is refractory to heat, that is no evidence that it is associated with coal. There are many refractory clays that do not occur in coal-measures. Some fireclays, however, have such characters as to be *prima facie* evidence of the presence of coal. In that case all one has to do is to look just above the clay for the coal. In general, the coal will be found before the clay. To call an ordinary clay or claystone a "fireclay" is quite a useless proceeding; it will not help one to find coal.

From my recent investigations and the information supplied to me it appears that the greywacke and argillite of Trias-Jura age that form most of the country near Picton, especially to the eastward, possibly contain small coal-seams. As I have already pointed out, it is no use prospecting small coal-seams except along the outcrop. Since the Trias-Jura rocks have steep dips, every bed forming them, including any coal-seams, must outcrop somewhere, unless an almost impossible combination of adverse conditions takes place. Hence prospecting other than by surface examination and trenching is needless. Driving, shaft-sinking, and boring are not required. In a hilly country, well dissected by streams, outcropping coal-seams of any thickness will reveal themselves by means of abundant pebbles of coal in the stream-beds for some distance below the outcrops. It may be pointed out that any coal in Trias-Jura rocks will be of such a quality (bituminous or near bituminous) as not to weather rapidly. Hence the coal, where it reaches the surface, will afford good outcrops, which, as stated, will supply abundant pebbles of coal to the neighbouring streams. The fact that the Trias-Jura series in the Picton district does not contain a typical coal-bearing series of rocks—*i.e.*, conglomerate, grit, sandstone, shale, &c., followed perhaps by marine strata such as calcareous sandstone and limestone—tells considerably against its coal-bearing possibilities. This is a logical though not conclusive argument. Against it, to some extent, is the fact that coal does occur in Trias-Jura strata in several New Zealand localities, including, it would seem, Picton itself. Since, however, the Trias-Jura rocks are widespread, and the seams are nowhere, so far as known, workable, and since, moreover, the Picton district has been well explored, it is highly unlikely that any coal profitable to work will be found in the rocks in question.

When fault-crushed the argillite and greywacke of the Trias-Jura rocks are apt to assume a black colour, and broken fragments may exhibit a polished lustrous surface superficially like some coal, and possibly due to an extremely thin coating of graphite. The surfaces, however, when scratched yield a light-coloured powder. Black shining rock of this kind is no indication of coal.

Lastly I may refer to the mistake made by those interested in Picton coal in not obtaining competent advice and following it. To be sure, the services of the Geological Survey have been requisitioned on many occasions, but the reports supplied have not been studied to advantage. Some of these reports, it is true, seem to be lacking in lucidity and in plain straightforward expressions of opinion, thus needlessly lessening their value to the prospector or the miner.

Even more valuable than the advice of a competent geologist would be that of a capable mining engineer. The ordinary coal-miner, whose experience is confined to the hewing of coal, timbering, &c., is useless as an adviser, but a qualified mine-manager, with good experience in directing actual mining operations, after a short inspection would certainly be able to state whether coal can be profitably mined at Picton or not. Some prospectors are also capable advisers on mining matters, but many men of this class are blinded by an invincible optimism, which leads them to exaggerate the possibilities of every find. Doubtless, however, a sanguine hopeful temperament is part of the mental equipment of every real prospector, leading him to follow up the slightest indication and to persevere in his search to the utmost.

Future Prospecting for Coal.

On the ground and at a later meeting I stated orally to Messrs. Allport and Webster that a little prospecting, if it could be carried out inexpensively, at the old Picton Coal-mine (Fell's) might not be amiss. I also thought that fresh search for the outcrops of coal found many years ago in the first, second, and fourth branches of Laymont Creek might be made. This advice is the same as that given by me in 1914. I must, however, make it clear that there is no prospect of more than a few hundred, or perhaps thousand, tons of coal being extracted at either locality. Picton coalfield is not a coalfield in the proper sense of the term; it contains irregular faulted patches of coal only, not continuous seams. I am not at all sanguine that further prospecting will disclose anything of value, and perhaps I ought to withdraw even the qualified advice just given. Long adits, if not on coal, are hardly worth while, and shaft-sinking below water-level must be emphatically condemned. Nor can I see that boring is advisable; in former days at least two bores were drilled to a reported depth of 200 ft. without success.

Unfortunately, no plans of the underground workings of the Picton Coal-mine were ever made, and the want of knowledge concerning the exact position and extent of the old workings must seriously embarrass the modern prospector in deciding on a scheme of operations.

Minerals other than Coal.

Graphite.—Graphite (plumbago, or black-lead) occurs in the ancient rocks of the Picton district. About 1882 Mr. John Renfrew forwarded a sample of graphitic slate to the Colonial Laboratory. In 1900 the Hon. Mr. Reeves forwarded a soft black shale from Picton, which contained—water, 18·24

per cent.; graphite, 2·64 per cent.; clay and sand, 79·12 per cent. (See "Graphite in New Zealand," N.Z. Jour. Sci. & Tech., vol. 2, p. 204, 1919.) If the graphite came from the Trias-Jura rocks south and east of Picton it is not likely to have any economic value, but an occurrence in the schists would perhaps deserve further investigation.

Cement Materials.—Limestone, clay, and coal are required in order to make Portland cement. Proximity of the works to a port is also desirable. Picton has, of course, an excellent harbour, and at The Elevation is a fairly large deposit of calcareous claystone suitable for cement-manufacture. Limestone, however, is the principal substance required for cement-manufacture, and of good limestone there is very little in the Picton district. Coal also does not occur in quantity, nor is it very probable that any can be mined on a commercial basis. The almost total lack of limestone condemns Picton as a centre for cement-manufacture, and thus the attempt made a few years ago to establish cement-works necessarily ended in failure.

Gold.—At Mahakipawa, a few miles west of Picton, gold was discovered many years ago. It is believed that much unwon gold yet lies beneath the surface of Mahakipawa Flat. The source of this gold is probably the schist range west of Picton, but no lode from which it could have been shed has yet been discovered. As bearing on the auriferous character of the schist it may be mentioned that a 5 oz. nugget is said to have been found on the Picton side of the range. A little desultory prospecting is still being done in the valley of Cullen Creek, &c.

Many years ago an auriferous-quartz lode was worked at Jackson Head, west of the entrance to Queen Charlotte Sound. Later a mine called the Golden Point was unsuccessfully worked by a Picton syndicate. It was situated on the north-western side of Queen Charlotte Sound, but I have not ascertained the exact locality. It is mentioned by McKay as being "on the north side of the sound, opposite Picton." (Rep. Geol. Explor. during 1878–79, No. 12, pp. 89–90, 1879.)

Antimony.—At one time an antimony-mine was worked with some success at Endeavour Inlet, a deep bay on the western side of Queen Charlotte Sound. Mining operations ceased many years ago.

Map.

The sketch-map herewith shows the approximate boundaries of the coal-measures near Picton and Shakespeare Bay. In order to illustrate the geology of the area correctly a good topographical map on a large scale is a necessity. The present map, therefore, cannot be accurate in every respect. It embodies some information taken from McKay's map of 1882, with which it agrees tolerably well. The detail is greater, and—a most important point—the principal faults are clearly indicated.

Conclusion.

In order to elucidate the somewhat difficult geology of the Picton district a lengthy examination, based on good topographical maps, would be necessary. The object of my recent visit, however, was not so much geological as to ascertain what were the coal-possibilities. Unfortunately, no reason for changing my opinion of 1914 (which was in agreement with that of other geologists) has been found, and my recent investigation simply shows more plainly than ever that the Picton district cannot be regarded as a potential coalfield. It may perhaps be said that the geology is difficult, and has not been thoroughly worked out. This may be correct to some extent, but the opinion expressed does not rest merely on geological details, but is founded on wide experience both of geology and mining.

The absence of a coalfield does not render a detailed geological survey of the Picton district unnecessary, but such a survey may be postponed until more important areas have been examined.

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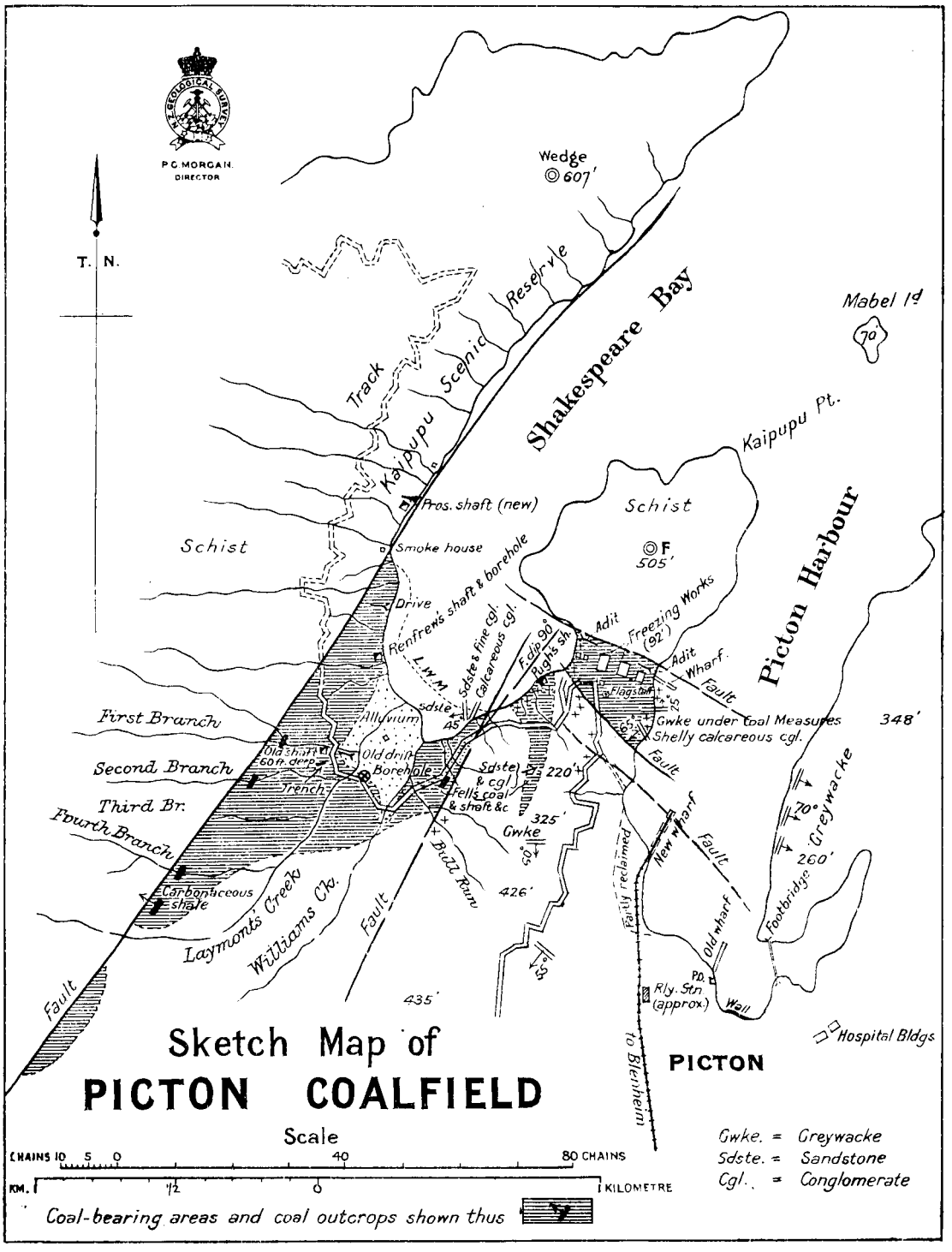
6. OIL-SEEPAGE NEAR WARD, MARLBOROUGH.

(By P. G. Morgan.)

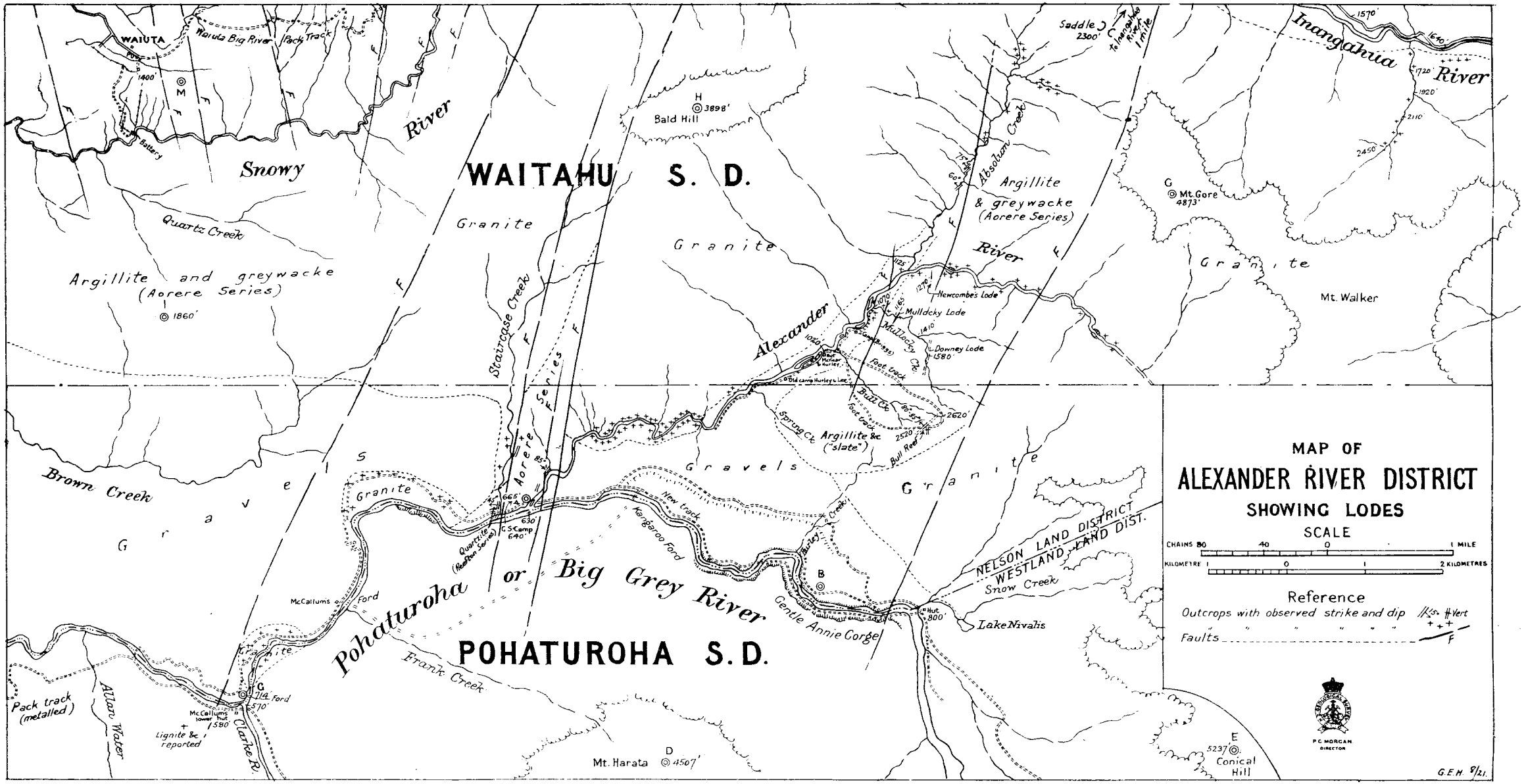
On the 25th August, 1920, accompanied by Mr. Richard Forrester, the discoverer, I visited a small oil-seepage or spring situated about three miles north-east of Ward. This occurs at a height of about 450 ft. above sea-level, on the north bank of a small stream, near its head. The locality, which is roughly two miles and a quarter south-east of Taimate Railway-station and rather over three-quarters of a mile north-north-east of the trig. station on London Hill, is included in Small Grazing-run No. 180 (Cape Campbell Survey District).

Very little can be said about the seepage. What one sees is a tiny pool of water containing small masses of yellowish buttery scum, and about a square yard of rock stained dark brown by oil. The rock out of which the oil is oozing, apparently very slowly, is a fine-grained much-jointed greywacke, probably of Jurassic age. The weathered surfaces of this rock are dark-coloured, but freshly broken surfaces exhibit a light-greyish tint. The joints are stained dark brown or almost black with oxide of iron, probably containing some manganese oxide. Greywacke is a rock of the same nature as sandstone, but the latter name can hardly be correctly applied to the rock out of which the oil is oozing.

The seepage of petroleum under discussion is of interest, since it issues from a rock older than any of the known petroliferous series of New Zealand, but is probably in itself not of great importance. The greywacke itself is too close-grained to be a good reservoir rock for oil, but the fact that it is much jointed counterbalances the close grain and renders the rock capable of holding and yielding a large amount of oil. Almost certainly, however, if oil were now present in quantity there would be one or more large seepages in the area where greywacke outcrops, owing to the facilities which the jointing of the rock affords for the escape of any contained petroleum. Hence on this account alone


N.Z. GEOLOGICAL SURVEY
P.G. MORGAN, DIRECTOR
T. N.
Wedge
607'
Reserve
Scenic
Track
Kaipupu
Shakespeare Bay
Mabel Id
70
Kaipupu Pt.
Schist
Pros. shaft (new)
Smoke house
Schist
F.
505'
Picton Harbour
Drive
Renfrew's shaft & borehole
Sdste & fine cgl.
Calcareous cgl.
L.W.M.
F.dip 90
Rights Sh.
Adit
Freezing Works (92')
Adit
Wharf
Fault
Flagstaff
Gwke under Coal Measures
Shelly calcareous cgl.
348'
First Branch
Second Branch
Third Br.
Fourth Branch
Old Shaft 60 ft. deep
Trench
Alluvium
Old drill Borehole
Sdste
45°
Sdste & cgl
Fells coal & shafts &c
220'
325'
Gwke
50°
426'
Butz Run
Fault
Laymonts Creek
Williams Ck.
Carbonaceous shale
Fault
435'
Fairly reclaimed
New Wharf
Fault
Old wharf
Foothridge
Greywacke
70°
260'
P.O.
Rly. Stn (approx.)
Wall
Hospital Bldgs
to Blenheim
PICTON
Sketch Map of
PICTON COALFIELD
Scale
CHAINS 10 5 0 40 80 CHAINS
KM. ½ 0 1 KILOMETRE
Coal-bearing areas and coal outcrops shown thus
Gwke. = Greywacke
Sdste. = Sandstone
Cgl. = Conglomerate

To face p. 18.]


WAITUTA
Waiuta Big River
Pack Track
1400'
Battery
Snowy River
WAITAHU S. D.
Bald Hill
3898'
Granite
Quartz Creek
Argillite and greywacke
(Aorere Series)
1860'
Staircase Creek
Aorere Series
Alexander River
Absolum Creek
Argillite & greywacke
(Aorere Series)
Saddle
2300'
to Inangahua River 1 mile
Inangahua River
1570'
1720'
1920'
2110'
2450'
Mt. Gore
4873'
Mt. Walker
Newcombe's Lode
Mulldcky Lode
Mulldcky Sty Cr
Downey Lode
1580'
Old camp Hurley's Lode
foot track
Bull Cr
Spring Cr
Argillite &c ("slate")
Bull Road
2620'
2520'
Brown Creek
Gravels
Quartzite (Reefton Series)
665'
630'
C.S. Camp
640'
New track
Kangaroo Ford
Burley Creek
Pohaturoha or Big Grey River
Gentle Annie Corge
NELSON LAND DISTRICT
WESTLAND LAND DIST.
Snow Creek
Lake Nivalis
Hut
800'
McCallums Ford
Frank Creek
POHATUROHA S. D.
Pack track (metalled)
Allan Water
McCallums lower hut
580'
Clarke R.
570'
Lignite &c reported
Mt. Harata
4507'
5237'
Conical Hill
MAP OF
ALEXANDER RIVER DISTRICT
SHOWING LODES
SCALE
CHAINS 80 40 0 1 MILE
KILOMETRE 1 0 1 2 KILOMETRES
Reference
Outcrops with observed strike and dip
Faults
P.G. MORGAN
DIRECTOR
G.E.H. 9/21.

the possibility of petroleum occurring in commercial quantity is small. Further, the Ward – Cape Campbell district, in common with the greater part of Marlborough, has been so much broken and disturbed in all sorts of ways that nearly all the petroleum which may once have existed in the various rocks of the region must have escaped long ago.

The greywacke itself is of such a nature that very little oil could have originated in it; and hence it can never have been important as a source of oil, though, owing to its jointed nature, under certain circumstances it could have acted as a reservoir for oil produced in other rocks. It is not unlikely that the oil seen by me was produced in some other rock, and that owing to the disturbances in the strata alluded to above it has made its way into the greywacke and thence to the surface. The original oil-rock may have been any of the Cretaceous and Tertiary rocks that outcrop east and west of London Hill. It is not necessary to discuss the matter further in this report; all that need be said is that the oil-occurrence has practically no commercial possibilities. If a pit a few feet deep were sunk at the seepage a small flow of oil, probably a few gallons per day only, would perhaps be obtained. So far as can be seen, boring at the seepage or in the neighbourhood is inadvisable.

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7. THE TALISMAN MINE, KARANGAHAKE.

(By J. Henderson.)

I arrived at Karangahake on the 17th November, 1920, and left on the 20th, and within that time examined the lower workings of the Talisman Mine, the cores from the diamond-drill holes, the plans and sections of the mine, and the assay sheets. In addition, the resident manager, Mr. H. Stansfield, gave me much information concerning the nature and structure of the main lode and the country it traverses.

The Maria lode, which has yielded by far the greater amount of bullion won from the Talisman Mine, is contained in the great pile of volcanic rocks that forms Karangahake Mountain, a prominent peak on the western side of the Hauraki Range, overlooking from the south the junction of the Waitawheta and Ohinemuri rivers, seven miles south-west of Waihi. The lode, together with numerous less persistent parallel lodes, strikes in a general north-and-south direction and dips westward. The profitable ore occurs in patches of greater or less size, separated by portions of the lode in which the vein-material is poor, barren, or altogether absent. The ore-bodies, although erratically distributed, are grouped to form four irregular shoots or sections from north to south known respectively as the Woodstock, Talisman, Bonanza, and Dubbo sections. In the upper portion of the mine all the ore is oxidized, but rich sulphide ore occurs below the present drainage level in the Bonanza and, to a much less extent, in the Dubbo sections. Of late years the bulk of the bullion has been obtained from sulphide ore mined from these sections. The upper levels have long been abandoned, and the lower workings are approached by an adit driven southward from a point some 40 ft. above the level of the Waitawheta River. Near the entrance of this adit the Woodstock shaft has been sunk vertically to a depth of about 500 ft. In this, the main drainage-shaft, has been placed a Cornish pump capable of lifting 1,500 gallons per minute, but at present discharging about half that amount of water. At the end of the adit, about 1,700 ft. from the entrance, is the Talisman shaft. This is an incline shaft originally started as a winze to prospect the Talisman shoot, but now much enlarged and extended to tap the Bonanza section of the lode. Below the main adit, which reaches the Talisman section a little below No. 11 Talisman level, four levels have been opened from the Talisman shaft. Another, No. 16, is reached by winzes from No. 15 level. The main drainage-tunnel from the bottom of the Woodstock shaft reaches the Talisman shaft midway between Nos. 14 and 15 levels.

The bulk of the ore from the Woodstock section has been won from above the main adit, though ore has been stoped for 100 ft. lower. All this ore was oxidized. The level south from the bottom of the Woodstock shaft penetrated sulphide ore of moderate value and small amount.

In the Talisman section ore has been stoped from the surface to No. 13 level, 1,500 ft. below. The ore was oxidized and generally of moderate value, though in the lower levels some of it was rich.

The Bonanza section contained oxidized ore to a depth of 500 ft. below the surface. For 350 ft. below this the fissure dipped less steeply, and the vein-material was narrow and contained little bullion. About 200 ft. above the level of the lowest adit oxidized milling-ore again appeared, and continued downward to drainage level, where it gave place to rich sulphide ore. This continued downward, occupying more and more of the fissure, to No. 14 level, over 400 ft. below the cap of the sulphide ore. In No. 15 level, about 140 ft. below No. 14, the rich ore was discontinuous and the length over all much less. Below this, though the siliceous vein-filling is of average thickness, the bullion content is less and still more patchy.

The Dubbo section near the surface yielded a little oxidized ore; then for 1,300 ft. in depth the lode contained only trifling patches of ore. In No. 13 level high-grade sulphide ore was found, and this continued downward, though not in large amount, to below No. 15 level, a vertical distance of over 400 ft.

Unoxidized vein-material consists of quartz containing gold and sulphides in variable amount. It is termed " ore " if its bullion content is such that it can be mined and milled at a profit. In the Bonanza section, vein-material without change in thickness, but worth but a few shillings per ton, continues downward below rich ore. The change takes place with little alteration in the appearance of the lode-material. Perhaps the banding is not so prominent as in the rich ore, but sulphides of iron, zinc, and copper are as abundant, although they are more coarsely crystalline. The transition from high-grade ore to almost barren vein-material takes place in a few feet, but in places alternations of high- and low-grade quartz occur. The bottom of the Bonanza ore-body is highly irregular, and rich ore follows breaks and leaders in the country in long narrow extensions downward along the lode.

The Maria lode traverses a great mass of volcanic material, of which the upper part is a spherulitic rock decidedly more siliceous than the underlying rocks. This rests on a massive andesite that overlies a great thickness of andesitic breccia, in places containing bands of well-bedded fine-grained subaqueous tuff. All these rocks have been propylitized—that is, altered by heated solutions rising through fissures, and presumably derived from great bodies of underlying molten rock. Lodes occur only in the propylitized rock, and in any district they carry ore-bodies only in some varieties of propylitized rock. Such "kindly" country differs in appearance from country in which the lodes do not carry ore-bodies, although the difference is not easy to describe. But "kindly" country has a much wider distribution than ore-bodies, and its presence cannot be held to prove that lodes traversing it will contain ore. Thus the three boreholes drilled from crosscuts in the hanging-wall of the lode in No. 15 level, to prospect the Maria vein below the lowest workings, in each case penetrated "kindly" country before reaching the lode, which, where passed through, consisted of barren quartz of average thickness.

Ore-bodies similar to those occurring at Karangahake are generally admitted to have been formed by descending surface waters concentrating ore-material contained in pre-existing poorer lodes or disseminated through masses of rock. The evidence for such an origin for the Maria lode is strong, and includes the following:—

(1.) The veins of quartz and bands of silicified country decrease greatly in number in depth. Instances are known of quartz veins changing in depth to fissures filled with broken rock and pug. Had the material been deposited by ascending solutions the number of quartz veins should remain the same or increase with depth.

(2.) The quartz forming the bulk of the vein-material varies greatly: some is chalcedonic; the rest is crystalline, ranging from very fine to coarse; some replaces calcite, some country; none has been seen showing the strain phenomena considered to be characteristic of quartz deposited by hot solutions rising from below. At Golden Cross, near Waitekauri, a quartz lode in depth changes to a calcite lode; this suggests that the replacement of the calcite proceeded from the surface downward.

(3.) Rich ore occurs more commonly on the hanging-wall side of the lode. Ore-bodies tend to be associated with leaders and fractures that leave the main lode, or with changes in the direction of the lode, where leaders generally continue into the country in the same course as the lode. Faults are often associated with ore, which tends to occur on their hanging-wall side. These phenomena are more likely to have occurred if the depositing solutions were descending than if they were ascending.

(4.) The distribution of the mixed sulphides in the rich ore of the Bonanza section suggests that they were deposited by descending solutions. The greatest proportion of the least soluble sulphide occurs in the upper part of the ore-body, and the greatest proportion of the most soluble in the lowest part. In fact, the unoxidized portion of the ore-body is roughly zoned horizontally according to the relative solubility of the various sulphides.

The bottom of the Bonanza ore-body has undoubtedly been reached. The rich ore that occurs associated with a small fault in the Dubbo section at the southern end of No. 15 level may continue some distance lower, perhaps even to No. 16 level. The drive south from the winze that passed through this ore will prove whether this is the case or not. Explorations of the lode below the ore worked in the other sections of the mine have exposed at most but trifling patches of ore, and the prospecting-work undertaken can have missed no large ore-body. North and south along the vein several of the drives are said to have been extended well into unfavourable country. The Maria lode has been thoroughly prospected, and the only ore remaining is in small extensions of the known ore-bodies of the Bonanza and Dubbo sections, now practically worked out. That this ore can be extracted at a profit is doubtful.

The Maria lode is the best-defined and most persistent in the Karangahake district, and has yielded the bulk of the ore won. The many crosscuts from the workings confirm the hypothesis that it carries ore to a greater depth than any other vein. Therefore exploration of any of the other veins will in all probability be quite as unsuccessful as that of the Maria lode. The view that lodes of the type found at Karangahake become in depth unprofitable to work is confirmed alike by theoretical reasoning and by practical experience in all mining districts where lodes of this nature are found.

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8. ALEXANDER RIVER REEFS, REEFTON GOLDFIELD.

(By P. G. Morgan).

In accordance with instructions given by the Hon. the Minister of Mines I made an inspection of the Alexander River district between the 17th and 20th May, 1921. The observations made during the visit are embodied in the following report:—

Situation.

The Alexander River reefs are situated in a narrow belt of argillite and greywacke (the "slate" of the miner) between Stevenson's Flat, on the Inangahua River, and the so-called Big Grey or Pohaturoha River (the main branch of the Grey River). To the west this belt is bounded by a granite area culminating in Bald Hill (3,898 ft.), and eastward by another granite area of rugged

topography having Mount Gore (4,873 ft.) as its most prominent feature. The "slate" area, though relatively depressed, varies in height above sea-level from about 1,000 ft. to 3,000 ft. Access at the present time is difficult.

The Lodes.

For many years quartz lodes have been known to exist in the Alexander River district, but until recently none of a promising character had been found. A few months ago James Hurley and Loftus McVicar, two prospectors subsidized by the Mines Department, discovered the Bull reef, which has caused so much excitement during the past two months. Since then several other lodes have been found. Of these the most notable are the Downey and Mullocky reefs, in Mullocky Creek, a small tributary of the Alexander River.

Bull Reef.

The Bull reef outcrop is situated near the top of the high spur between the Alexander and Grey rivers, at an elevation of about 2,500 ft. above sea-level. It has been exposed in four trenches, the most northerly of which, No. 1, is less than a chain and a half from the most southerly, No. 4. As seen in these trenches the lode strikes or trends 30° east of magnetic north—that is to say, about north-east on a true bearing—and dips steeply (80° to 85°) to the north-west. The slaty country enclosing the lode, however, as seen in a trench a few yards south of No. 4 trench, seems to strike about due north and south, and to have a vertical dip.

The quartz broken out from the trenches is of a kindly appearance. It varies in colour from white to bluish; some is slightly iron-stained, and a few little crystals of iron-pyrites may be seen. Many lumps of the broken quartz show numerous but rather small colours of gold, and the stone has been estimated to go perhaps 2 oz. to the ton; but, from the assays quoted below, this estimate, moderate as it is in comparison with some of the accounts published in the newspapers, unfortunately appears to be well over the mark. A hundredweight or more of richly auriferous quartz broken from the outcrop was seen by me at the prospectors' camp and elsewhere, but none of the quartz visible *in situ* was of this character.

Width and Value of Reef.—In the most northerly, or No. 1, trench the reef shows fully 7 ft. of quartz. This and the other trenches were sampled by Mr. J. F. Downey, Inspector of Mines. The sample from No. 1 trench on being assayed at the Reefton School of Mines gave the following results:—

	Gold, per Ton.	Silver, per Ton.	Value, per Ton. Nominal. £ s. d.	Value, per Ton. Average. £ s. d.
(A)	18 dwt. 7 gr.	1 dwt. 7 gr.	3 13 3	3 14 7
(B)	18 dwt. 23 gr.	..	3 15 10	

B was a check assay. I have calculated the value on the ordinary assay-office assumption that gold in the stone is worth £4 per ounce and silver 2s. per ounce. At the present time perhaps 20 per cent. could be added to these values.

In No. 2 trench, about 15 yards south-west of No. 1, the reef as exposed is 3 ft. wide. Mr. Downey's sample, taken over this width, assayed only 1 dwt. 23 gr. gold per ton, giving a nominal value of 7s. 10d. per ton.

The lode at No. 3 trench, 8 yards south-west of No. 2, is 4½ ft. wide. Mr. Downey's sample on assay yielded 4 dwt. 14 gr. gold per ton, equal to 18s. 4d. per ton.

The lode at No. 4 trench, about 9 yards south-west of No. 2, is 6 ft. wide. The quartz is of good appearance, but Mr. Downey's sample yielded on assay only 1 dwt. 23 gr. gold per ton, or a value of 7s. 10d. per ton. I sampled the loose quartz lying about by breaking small pieces off fifteen or sixteen typical lumps. The sample, assayed at the Dominion Laboratory, yielded only 1 dwt. 10 gr. gold per ton, or a value of 5s. 8d. per ton, thus confirming the unexpectedly low result given by Mr. Downey's sample.

The average width of the Bull reef or lode as exposed in the trenches is a little over 5 ft. (5 ft. 1½ in.), and the average value of the outcrop quartz, as calculated from the assays of Mr. Downey's four samples, is £1 7s. 2d. Even if 20 per cent. is added to this value, in order to allow for the appreciated price of gold at the present time, the outcropping quartz cannot be regarded as payable under present conditions. It is true that a small amount of rich stone, none of which was included in the samples, has been obtained from the trenches, but as none of this was seen by Mr. Downey or myself *in situ* obviously no allowance for its presence can be made. There may not be more than a small pocket of such material, and it seems quite certain that the rich stone is not in a continuous band or seam along the lode, otherwise it would have been seen by me, and the assays of Mr. Downey's samples from trenches Nos. 2, 3, and 4 would have been much higher.

General Remarks on the Bull Reef.—The Bull reef needs to be prospected to a much greater extent than has yet been done before one can form a true estimate of its prospects. In the first place, more trenches are necessary in order to find the length of outcrop, and thereafter one or more adits must be driven to cut the lode well below the line of outcrop. If the outcrop can be traced some distance north and south it will be possible to drive on the lode itself, instead of having to crosscut. The difference between the reports published in various newspapers and reality is so great that one finds it hard to form a dispassionate opinion concerning the occurrence. Disregarding all the statements I have heard or read, and relying only on what I have seen, I would say that the Bull reef is well worth prospecting. So far as exposed it is of workable width, it contains some payable ore, and may possibly yield an appreciable amount of high-grade ore. For the present, however, it would be best to take little account of the latter possibility. The lode, though at present difficult of access, is otherwise favourably situated for economical working. Mining-timber is abundant, and ample water-power for a battery, &c., can be obtained from the Alexander River and other streams.

Mullocky Creek Lodes.

About 13 chains up Mullocky Creek from the Alexander River the "Mullocky reef," a lode formation consisting of a mixture of crushed oxidized country rock ("mullock") and small quartz veins, outcrops on the north bank of the stream at a point 1,165 ft. above sea-level (barometric observation). It appears to strike about magnetic north (*i.e.*, a little east of true north). A sample taken over a width of 3½ ft. by Mr. Downey yielded on assay 1 dwt. 7 gr. of gold per ton. Since gold is present, the further testing of the Mullocky reef by a short drive is advisable.

At 51 chains by paced compass traverse up Mullocky Creek a massive quartz lode, the "Downey reef," outcrops on the north bank at a point about 1,580 ft. above sea-level. It strikes a little east of north, and probably dips almost vertically. At first, owing to the true strike not being distinguished, the width of the lode was estimated at 14 ft. or more, but as a matter of fact the actual width cannot be ascertained until the lode has been cut across at right angles to its strike. The width is certainly over 5 ft., and may be much more. A little up the hillside more quartz outcrops; this probably belongs to a parallel lode. The quartz of the Downey lode is rusty on the joint-surfaces, and shows bluish streaks when broken. Grains of iron-pyrites are fairly common away from the joints. A sample from the outcrop, taken by Mr. Downey over a width of 5 ft., on being assayed yielded 1 dwt. 7 gr. of gold per ton. This result is very low, but, seeing that the lode is large and the quartz of a fairly promising character, further prospecting by means of trenches along the outcrop, and perhaps by driving, is advisable.

Other Lodes.

Quartz outcrops in two places on the banks of Mullocky Creek, between Mullocky lode and Downey lode, but the occurrences seem to be unimportant.

A short distance north of the Bull reef outcrop, near the head of Bull Creek, I was shown an outcrop of white, rather glassy, quartz. I also saw several veins of quartz on the spur between Bull and Mullocky creeks. These have been trenched by the prospectors (J. Hurley and L. McVicar), and I was told that a little gold could be obtained from each by crushing and panning the quartz.

A few chains east of the junction of Absolum Creek and the Alexander River quartz intermixed with country rock outcrops over a thickness of several feet. The locality is at the south-west corner of a prospecting-area pegged out by Mr. Newcombe, and about 1,270 ft. above sea-level. A sample of the quartz taken by Mr. Downey assayed only 16 gr. of gold to the ton.

Small quartz veins are reported to outcrop near the Alexander River above Absolum Creek junction. Some years ago Dr. Henderson discovered a small quartz vein in Absolum Creek (Bulletin No. 18, p. 187).

Other quartz veins in the Alexander River district have been reported by recent prospectors. A piece of quartz which I saw, supposed to come from one of these finds, was of a favourable character.

General Remarks.

Until much more trenching and some driving has been done on the lodes it is not possible to state what the prospects of the Alexander River field really are. No mine or mining district can be safely judged by surface prospects alone, much less by the reports of biassed or non-technical observers. The Bull lode itself, the main feature of the field, in spite of all that has been said, remains a mere prospect, though one that deserves a thorough test. It offers possibilities to the speculator, but nothing that would tempt the cautious investor. Members of the public should not allow their judgment to be influenced by the fact that a small amount of tolerably rich auriferous quartz has been obtained, and before thinking seriously of investing in the supposed El Dorado should await the results that can be obtained by a moderate expenditure on trenching and driving.

Addendum.

During my visit to the Alexander an important observation was made—namely, that quartzite, evidently belonging to the same series as that near Reefton (Murray Creek), &c., outcrops on the north bank of the Grey River at the mouth of Staircase Creek, a few chains west of the Alexander River. The strike is east of north (204°), and the dip 45° to 50° to the westward. In the strong fault-zone which crosses the Alexander River 20 to 30 chains above its mouth are many fragments of quartzite. At one place evident fault-breccia is bounded on its west side by a conglomerate composed mainly of rounded fragments of quartzite, hornfels being the only other constituent noted. The layers dip at about 30° eastward. It is thought that the so-called conglomerate is possibly not a conglomerate, but really consists of pieces of rock broken and rounded by fault-movements. The hasty examination made, however, did not permit its true relations to be ascertained.

During March and April, 1860, Sir Julius von Haast was engaged in the exploration of the upper Grey Valley and neighbouring areas. He observed the quartzite at Staircase Creek, and thus described it: "On the western bank of the Alexander we meet, for the first time, with a sedimentary rock of newer origin than those of the central chain—an arenaceous sandstone of greenish-yellow colour, with veins of quartz, striking north and south, with a dip of 45° towards the west. In a few places casts of small shells are visible, but not sufficiently distinct to enable me to form any conclusion concerning them." ("Report of a Topographical and Geological Exploration of the Western Districts of the Nelson Province," p. 101, 1861.)

The quartzite and associated fossiliferous rocks of the Reefton district have sometimes been considered to be of Devonian age (as by Alex. McKay), and sometimes of Silurian age. According to a statement made by Mr. W. S. Dun the Reefton fossiliferous rocks should be correlated with the Baton River Series, and are approximately of Yeringian (roughly equivalent to Wenlock) age.

9. STONE FOR HARBOUR-WORKS, NEW PLYMOUTH.

(By P. G. Morgan.)

In accordance with the instruction of the Hon. the Minister of Mines I left Wellington for New Plymouth on the 16th June, 1921, in order to examine Paritutu and other possible sources of stone for the New Plymouth (Moturoa) harbour-works. While in New Plymouth, at the request of the Paritutu Preservation League Committee I made a special visit to the Pouakai Range in order to inspect an outcrop of rock reported to be suitable for harbour-works. On the 20th I returned to Wellington. My thanks are due to Mr. R. W. Davies, of New Plymouth, who motored me to various points requiring examination, and was my guide to the Pouakai Range. I also wish to acknowledge courtesies received from Mr. A. E. Watkins, and from the president (Mr. R. C. Hughes) and various other members of the Paritutu Preservation League.

Paritutu is the most prominent of the well-known Sugarloaves. Unlike the others, it is not an island, but rises almost perpendicularly from the edge of the sea, half a mile west of the base of the Moturoa breakwater, to a height of 505 ft. On the east, south, and west sides agglomerate deposits, capped by sand, mask its base to a height of perhaps 200 ft. or more. The hill itself is a plug of igneous rock, which in a bygone age rose in a fluid or semi-fluid condition from a molten mass of rock deep in the bowels of the earth through a vent which may be described as the throat of a volcano. Since that time it has been subjected to the usual geological vicissitudes, but appears to have lost little of its original dimensions—that is to say, its top and sides have not been greatly reduced by erosion. This view differs from that advanced by Mr. E. de C. Clarke in Bulletin No. 14 (pp. 21, 25), where Paritutu is regarded as formed of a lava flow or flows.*

The Paritutu rock is a hornblende-andesite similar to that forming the other Sugarloaves. On the whole it is in a fairly fresh condition, but is somewhat affected by weathering, especially near joint-planes. The rock forming the north-eastern face of the hill is highly jointed, and even shattered; elsewhere it is more solid, and joints are much less prominent, but flaws are abundant. The hill is so situated as to offer unusual facilities for quarrying. All that is needed to destroy the upper 300 ft. is a few hundred feet of drives and, say, 100 tons of explosive. The larger masses of rock, although they will not be of the highest quality, will be suitable for the construction of a rubble mole or breakwater. I am of opinion that the proportion of small stone will be large; but since the cost of quarrying will be low, since much of the small material can be used for the breakwater-construction and since the remainder can be easily tipped into the sea, this will not be considered a serious objection from the utilitarian point of view to the proposed destruction of Paritutu.

A blast has already been fired on the south side of Paritutu, and is said to have dislodged 30,000 tons of rock. Personally, I would place the amount at somewhat less, but it is certainly well over 20,000 tons. According to a newspaper report (*Taranaki Herald*, 11th June, 1921), Mr. J. Blair Mason, consulting engineer to the New Plymouth Harbour Board, has reported that 20 per cent. of the broken rock is in masses of 2 tons to 30 tons, 30 per cent. in ½-ton to 2-ton sizes, 35 per cent. in lumps of ½ cwt. to ½ ton, and 15 per cent. in small lumps. All the material, he states, can be used in the breakwater-construction. So far as I could judge from an inspection of the broken rock this estimate is fairly near the mark. Part of Paritutu, however, will yield very little large-dimension stone. It may be observed that about 1879 Mr. Rees, then Engineer to the New Plymouth Harbour Board, reported that Paritutu would yield only 10 per cent. of stone in large lumps (from ½ ton upward was, I think, his statement); and on the strength of this report Sir John Coode advised that a breakwater in the form of a concrete monolith should be constructed. I think that the upper 300 ft. of Paritutu will yield less than 20 per cent. of dimension stone (2 tons and upward), but probably more than 10 per cent. The lower 200 ft. (down to sea-level) may be somewhat better in this respect than the upper 300 ft., but there is no certainty about this.

A tram-line for the removal of the dislodged stone is under construction, but no further quarrying-work was being done at the time of my visit.

As requested by the president of the Paritutu Preservation League in his letter of the 31st May I examined the quarry at the Fishing-rocks (Motukuku and Ngataierua), between Paritutu and the breakwater. This quarry has been worked by the Harbour Board almost to high-water level, and must be regarded as exhausted. It was suggested to me that the quarry could be worked downward, below sea-level; but only a comparatively small amount of stone could be obtained in this way, and in any case the expense of quarrying under adverse conditions renders the proposal impracticable.

An attempt to quarry stone for harbour-works on the little island of Moturoa, which is less than half a mile north-west of the present breakwater, has lately been made. Some time ago this was abandoned owing, it is stated, to the lack of sufficient labour.† The island has been disfigured and a considerable expenditure incurred in this undertaking, which so far has been resultless.

The small Sugarloaves, Pakaraki, Mataora, and Motu-o-Tamatea, south-west of Paritutu, are composed of close-jointed andesite, and if quarried would afford only a small amount of large-dimension stone. I am informed that Motumahanga, or Saddleback Island, the Sugarloaf farthest to the north-west, is composed of good solid stone; but the island is in an exposed situation, and the cost of transporting the stone from it to its final resting-place would be great.

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*I am indebted to Professor W. N. Benson for drawing my attention to Alexander McKay's statement that Paritutu is a perfect example of a volcanic core. See Sollas and McKay: "Rocks of Cape Colville Peninsula," vol. 2, p. 162, 1906.

†As originally written this report stated that the work had been abandoned owing to the poor quality of the stone and the cost of transport. (See New Plymouth papers of January, 1921.) Messrs. Blair Mason, Lee, and Owen, however, in a letter dated 20th July, 1921, state that the work was discontinued solely because labour was not available at the time; and the report as now printed has been altered to conform with this authoritative statement.

The volcanic agglomerate which occurs immediately below the soil and subsoil of the district surrounding New Plymouth contains numerous boulders of andesite up to 10 ft. in diameter. These have accumulated at the base of sea-cliffs—for instance, between Oakura and the Sugarloaves—and in the stream-beds. They are suitable for breakwater-construction, but the cost of collection and transport would be prohibitive.

There are some inland quarries—for example, Hawk's Hill, on Frankley Road—which could furnish large blocks of stone. In all cases, however, the supply at any one spot is small, and the cost of transport to the breakwater would be prohibitive.

Unlimited supplies of large-dimension stone of splendid quality can be obtained from various parts of Mount Egmont and the Pouakai Range. The only deposit of this nature near a railway-line is some distance west from the present terminus of the Mount Egmont Branch Railway (Public Works Department), which runs a little south of west from Waipuku Railway-station to the lower slopes of Mount Egmont. At its terminus, 2,160 ft. above sea-level (barometric observation), is a quarry in volcanic agglomerate. The massive outcrop of andesite said to be two miles to the westward of this point has not been visited by any officer of the Geological Survey, but as a report by Mr. G. W. B. Lowson, Engineer to the New Plymouth Harbour Board (published in the *Taranaki Herald*, 21st January, 1921) states that the stone is in unlimited quantity and obtainable in large blocks, I do not doubt that the stone here is highly suitable for harbour-construction. Mr. Lowson states that the stone will be supplied by the Public Works Department on trucks at 5s. per ton, and that the cost of railage to Moturoa will be 5s. 7d. per ton, making the total cost per ton 10s. 7d.

The rock outcrop on the Pouakai Range inspected by me is situated on a high spur between Kiri and Momoma creeks, tributaries of the Oakura River, within the Mount Egmont Reserve. The rock-face actually seen is at an estimated height of 2,800 ft. above sea-level. It consists of massive hornblende-andesite, which is of excellent quality and can be broken in blocks of any size. According to Mr. R. W. Davies, of New Plymouth, who was my guide to this spot, there is a high cliff on the Momoma Creek (south) side, from which the stone could be shot down into the creek to a point accessible by tram-line. The distance from this point to Moturoa or to New Plymouth is between eleven and twelve miles as the crow flies, and a railway of, say, thirteen miles in length would have to be constructed before stone could be delivered to the harbour-works. Owing to the cost of making such a railway, and the time necessarily involved, the suggestion that the deposit between Kiri and Momoma creeks can be used seems at present impracticable.

Under present conditions the only source of stone for the New Plymouth harbour-works that enters into competition with Paritutu is the deposit two miles beyond the present terminus of the Mount Egmont Branch Railway. This stone, there is reason to believe, is of better quality than the Paritutu stone, but it will cost much more per ton landed at the harbour-works. Moreover, it cannot be supplied at all until the railway (or a tramway) is extended to the quarry-site. It is possible that the railage (5s. 7d. per ton) can be considerably reduced; if so, the higher quality of the Mount Egmont stone as compared with the Paritutu stone, and the fact that its quarrying will not involve the destruction of a monument of great natural and historical interest, may well compensate for a somewhat higher first cost.

In concluding I would like to observe that the question of whether Paritutu is to be destroyed or not is only in small measure a matter for a geological report. It happens that the hill is so situated that it appeals to the Harbour Board and its engineers as a probable source of cheap material for harbour-works, whilst, on the other hand, its destruction will cause regret to every one who has an artistic sense and is able to realize that there is something more in life than mere utilitarianism. Under the circumstances it appears to be desirable that the Harbour Board and its engineers, before proceeding further with the destruction of Paritutu, should show that this course is absolutely necessary and that there is no practical alternative.

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10. SUPPOSED LIGNITE AT UMUTAOROA, NEAR DANNEVIRKE.

(By P. G. Morgan.)

In accordance with instructions I visited a supposed lignite-outcrop at Umutaoroa, near Dannevirke, on the 15th September, 1920. The outcrop is situated on Section 29, Block 13, Norsewood Survey District, the property of Mr. D. Barry. The locality is about seven miles north of Dannevirke. Here, at a barometric height of roughly 1,050 ft., on the east bank of a small tributary of the Mangatera Stream, a thick band of dark-coloured material is visible. In the main this consists of rather poorly carbonaceous shale, enclosing small masses and layers of carbonized wood or lignite. The layers strike 254°, and dip at about 25° to the west of north.

Containing, as it does, only a small percentage of combustible matter, the supposed lignite is of no commercial value.

The following analysis of a sample forwarded some time ago by Mr. Barry to the Dominion Laboratory represents material that is useless as a fuel, and yet is certainly much higher in combustible matter than the average of the deposit inspected by me:—

Lignite from Umutaoroa Block, Dannevirke.

Fixed carbon	20·5
Volatile hydrocarbons	25·5
Water	20·7
Ash	33·3
	100·0

Dr. Maclaurin remarks: "This is a lignite of poor quality, containing an excessive amount of ash."

11. WAIPATIKI OIL-WELL, NEAR WEBER.

(Summary of Report by P. G. Morgan.)

On the 16th September, 1920, I visited the bore being drilled by Waipatiki Oil-wells (Limited), at Waipatiki, about three miles north-west of the township of Weber. This bore, formerly known as "Kotuku Oilfields bore No. 1," is on Oparae Road, three-quarters of a mile south of its junction with the Dannevirke–Weber Road. The chief reason for drilling here was the existence of a large gas emanation or spring in the neighbourhood. When its No. 1 bore had reached a depth of 2,336 ft. the Kotuku Oilfields Syndicate suspended drilling, and concentrated its efforts on No. 2 bore, some distance to the south, on Mr. A. D. Herrick's land. At a depth of about 3,000 ft. this bore entered a hard light-grey rock, most likely of greater age than the possible petroliferous beds. The Kotuku Oilfields Syndicate then ceased drilling. Some time later its plant was sold, and in the end was acquired by the Waipatiki Oil Company, which later became Waipatiki Oil-wells (Limited). This company decided to deepen No. 1 bore, and at the time of my visit its depth was about 3,600 ft. The rock being penetrated was calcareous claystone, stated to yield "shows" of oil.

It is quite possible that, as the shareholders hope, oil in quantity will be struck by continuing the bore, and hence the boring operations cannot be condemned outright. At the same time the prospects of this one bore, considered by itself, are not, in my opinion, bright. Since, however, no detailed geological survey of the district has been made, the most important factor for forming a reliable opinion is wanting.

The known evidence for and against the occurrence of petroleum in quantity in the Waipatiki district may be summed up as follows:—

(1.) Dr. J. Wanner, a well known oil-geologist, in 1911 reported favourably on the Weber (Waipatiki) district as a possible oilfield.

(2.) Near No. 1 bore is a large gas-emanation. The composition of the gas favours—and in fact almost proves—the view that it is associated with petroleum. Other gas springs occur in the district. On the other hand, the petroleum may be only in small quantity, and many natural-gas occurrences are not directly associated with profitable accumulations of petroleum.

(3.) On Mr. Frank Giddens's farm at Pukehinau, south of Waipatiki, a greasy substance occurs in the ground close to a gas spring. This material has been described as like ozokerite, but it burns with difficulty, and is perhaps dopplerite. It may possibly be much the same as the "paraffin dirt" of Texas (a peaty substance), which is generally regarded as an oil-indication.*

(4.) Petroleum undoubtedly does exist in small quantity in the strata being bored, but there is no evidence of large accumulations or "pools."

(5.) The strata are of a character favourable for the formation of oil.

(6.) The structure of the strata appears to be favourable for the accumulation and retention of petroleum. On the other hand, the existence of an "oil-sand" or stratum capable of acting as an oil-reservoir has not been proved.

As is now almost universally admitted, detailed geological survey should precede oil-drilling, for, although the existence of oil in quantity can be proved only by drilling, the fixing of bore-sites by geological survey greatly increases the chance of early success if oil should be present. If, however, oil is lacking in an apparently promising locality a few boreholes directed by the geologist will give practically absolute proof of its non-occurrence, and will save much useless boring.

There is a fair prospect of petroleum being found in payable quantity somewhere in southern Hawke's Bay or eastern Wellington, but geological survey is the first essential, not boring.

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12. SUPPOSED COAL-MEASURES, LAMB VALLEY, NEAR GLENHOPE.

(Summary of Report by P. G. Morgan.)

On the 16th February, 1921, I inspected the area being prospected by the Lamb Valley Prospecting Syndicate, situated in Blocks III and VII, Hope Survey District, near Glenhope, Nelson. A short adit (100 ft.) had been driven by the syndicate on the east side of a small tributary of Lamb Valley Stream, in soft claystones and sandstones resting on decomposed granite and dipping to the north-east. The locality is about 1,350 ft. above sea-level, and a little over three-quarters of a mile south-east of Glenhope Railway-station. Some of the claystone layers were carbonaceous, and contained numerous pieces of carbonized wood, but there was no defined seam of coal, and in my opinion no prospect of any being found in that locality.

Half a mile to the south claystones with carbonaceous layers are seen on the roadside resting on granite. These beds strike 145°, and dip at 15° to 30° to the north-east.

A bluff on the east side of the Hope River, half a mile north-east of the Glenhope Railway-station, was found to be composed of claystone, sandstone, and conglomerate, containing several carbonaceous seams and numerous pieces of lignitized wood. Similar beds occur farther north towards Tadmor Saddle.

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* A. D. Brokau: "Interpretation of so-called Paraffin Dirt of Gulf Coast Oilfields." Trans. Amer. Inst. Min. Eng., vol. 61, pp. 482–509 (with discussion), 1920. Peaty material of the same nature as "paraffin dirt" occurs in Taranaki, associated with gas-escapes (see N.Z. Geol. Surv. Bull. No. 14, pp. 27, 43, 45; 1920).

The sedimentary strata so far mentioned are evidently of younger age than the true coal-measures of Nelson, and the prospect of finding workable coal in them is practically nil. The numerous drifted lumps of carbonized wood and the poorly carbonaceous seams of claystone or shale in these rocks are not trustworthy indications of the presence of coal.

A great fault or fault-zone, which may be called the Hope fault, bounds the western side of the Hope Valley. It continues northward over Tadmor Saddle, and some years ago was observed west of Kaka Railway-station by Dr. J. Henderson.

After my visit to Glenhope a small piece of carbonaceous shale from a point some distance south of Lamb Valley was sent to me. This was highly slickensided, and I expressed the opinion that it might be associated with actual coal-measures. That this was the case seems to be shown by the fact that the discovery of a seam of bituminous coal in the neighbourhood has since been reported. The accounts of the size of this seam are conflicting. It is said to be situated about 150 yards east of the coach-road, at a point two miles south of Glenhope Railway-station.

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13. SUPPOSED OIL-SHALE NEAR MANGONUI, NORTH AUCKLAND.

(Summary of Report by H. T. Ferrar.)

The writer arrived at Mangonui on the 15th December, 1920, and on the same day examined the lignite at Cooper's Beach. During the next two days he examined the shale-outcrops on Section O.L.C. 9* (J. Matthews), and Section 7, Block VIII, Rangaunu Survey District, which are being prospected by the Mangonui Coal-prospecting Syndicate. The surrounding country was also explored.

The shale-exposures which were specially inspected are south of Lake Ohia, and eight or nine miles west of Mangonui. They occur on the northern side of a flat-topped ridge 100 ft. to 150 ft. high, with a length from east to west of about a mile and a half, and a width of half a mile. The greater part of the ridge consists of black carbonaceous mudstone or shale, with a brown streak. Several samples were collected for further examination, and three of these were sent to the Dominion Laboratory for analysis. Dr. Maclaurin's report is as follows :—

Oil-shale from Mangonui.—Proximate Analysis.

	No. 3.	No. 4.	No. 5.
Fixed carbon	5·86	5·85	4·35
Volatile hydrocarbons	14·28	13·06	12·06
Water	1·32	1·09	1·13
Ash	78·54	80·00	82·46
	100·00	100·00	100·00
Sulphur (per cent.)	2·18	1·69	1·88

For distillation equal weights of each sample were taken, and the mixture distilled with the following results :—

	Gallons per Ton.
Total crude oil	5·5
Yielding (fractionation) :—	
Light oil up to 100° C.	2·20
100°–300° C.	0·88
300° C.	1·32
Residue, tar, &c.	1·10
	5·50

Although the Mangonui shale is far too low-grade to be worked as an oil-shale, yet such material is a possible source of petroleum—not, of course, in the locality where it outcrops, but in areas where it is buried in contact with a suitable oil-reservoir rock, and where the structure is favourable for the accumulation of oil. It may be pointed out that extensive deposits of carbonaceous or so-called "bituminous" shale occur in other parts of North Auckland, which deserve consideration when detailed examination of those areas comes to be made.

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14. OAMARU HARBOUR DISTRICT.

(Summary of Report by J. Marwick.)

During the early part of May, 1921, the writer examined numerous localities in the Oamaru district with a view to finding deposits of stone suitable for harbour-works.

(1.) *Near Peebles.*—On the summit of Big Hill, south of Peebles, is a band of quartz-pebble conglomerate with a ferruginous cement. The same conglomerate caps other hills in the neighbourhood. Its thickness is probably from 15 ft. to 20 ft. Owing to the height of the conglomerate-outcrops above the Waitaki Valley plain, and the steepness of the 700 ft. slope below them, transport will be difficult. Waste material will have to be kept out of the Oamaru Borough water-race, which runs at the foot of the slope.

* O.L.C. = Old land claim.

(2.) *Ngapara.*—On the north side of the road east of Ngapara conglomerate similar to that near Peebles occurs as a horizontal band, probably about 15 ft. thick, near the top of the hills. Large blocks of rock can be obtained here, and the locality is much more accessible than that near Peebles. There is, however, uncertainty as to the amount of stone obtainable. In order to ascertain this excavations would have to be made at various points.

(3.) *Waikaura.*—At Waikaura, a quarter of a mile south-east of the railway-station (thirty-one miles from Oamaru), limonitic conglomerate outcrops at the mouth of a small creek entering the Waitaki Valley plain from the high country to the south. An accurate idea of the thickness and extension of the deposit cannot be obtained without exploration.

(4.) *Waimate Gorge (South Canterbury).*—The gorge is excavated in greywacke, of which there is an unlimited quantity, but the rock is much jointed, and the chances of obtaining large-dimension stone in any quantity are small.

(5.) *Kakanui Gorge (Four Miles west of Windsor).*—The schist in this locality has many bedding-planes, and is much too jointed to supply large blocks.

(6.) *Herbert and Waimotu.*—The hills (Mount Charles and others) south-east of the township are capped by dolerite. The rock is deeply weathered ; no blocks over 3 or 4 tons weight were seen, and no great thickness of stone seems to exist.

The dolerite on Gale's property, between Herbert and Waimotu, was seen only as boulders, which probably came from a dyke. If so, no great amount of rock is available.

Volcanic rock outcrops in the bed of a creek 200 yards north of Waimotu Railway-station. This was seen only from the train, and is possibly worth further examination. It may be an extension of the Mount Charles dolerite.

(7.) *Oamaru Harbour Board Quarries at Cape Wanbrow.*—The two faces on the north side of Cape Wanbrow are in volcanic breccia. This stone is very irregular in quality. A small proportion of large stones up to 10 tons weight would be obtained by using large blasts, but the waste would be very great. If tipped into the sea the waste might accumulate to form a protecting apron for the breakwater, but whether this would happen depends on the ocean-currents and the direction of the breakwater. Volcanic breccia outcrops on the shore-line below the lighthouse as far round as Boat man's Harbour. Some blocks of stone up to 10 tons weight may be obtained from this locality, but the overburden is so great that the expense of opening a quarry is not warranted. The pillow-lava outcropping along the shore from Boatman's Harbour for some distance southward is of such a character as not to be likely to yield many large blocks.

(8.) *Quarries in Oamaru Creek Valley.*—The quarry facing Chelmer Street has long been disused. The rock is a soft-bedded tuff, unsuitable for harbour-work. Northward several quarries have been opened in a thick flow of basalt or dolerite which outcrops on both sides of the valley. The rock is hard and heavy, but is closely jointed wherever seen, and will yield few, if any, large blocks.

Conclusion.—Of the more accessible localities visited, Ngapara is the most likely, but (as previously pointed out by Dr. J. A. Thomson) the amount of stone available is not great. It may perhaps be practicable to build the main body of the breakwater with the volcanic breccia of the Harbour Board quarries, and to face the outside with large blocks of the Ngapara conglomerate.

Some consideration was given to the possible use of Waitaki limestone for the breakwater. Fragments of this stone that have been lying in the harbour for twenty years or so show softening and a certain amount of pitting, which is evidence of solution by sea-water. It is considered that such stone would be unsuitable for use in an exposed situation. Softening, solution, and erosion would probably proceed more rapidly than in the sheltered harbour-water.

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