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Department of Mines.

GEOLOGICAL SURVEY BRANCH.

(P. G. MORGAN, Director.)

BULLETIN No. 17 (NEW SERIES).

THE GEOLOGY AND MINERAL RESOURCES

OF THE

BULLER-MOKIHINUI SUBDIVISION,

WESTPORT DIVISION.

BY

PERCY GATES MORGAN AND JOHN ARTHUR BARTRUM.

ISSUED UNDER THE AUTHORITY OF THE HON. WILLIAM FRASER, MINISTER OF MINES.

WELLINGTON.
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1915.

LETTER OF TRANSMITTAL.

Geological Survey Office,
Wellington, 15th March, 1915.

Sir,—

I have the honour to submit herewith Bulletin No. 17 (New Series) of the Geological Survey Branch of the Mines Department.

This bulletin forms a comprehensive report on the geology and mineral resources of the Buller-Mokihinui Subdivision, which includes the whole of the Buller coalfield, as well as less important mining-areas. It contains 210 pages of letterpress, and is illustrated by a large number of plates, figures, maps, and sections.

The geological field-work in connection with this report was done mainly by the senior author. For several months Mr. J. A. Bartrum, Assistant Geologist, was in the field, and some assistance was also given by Dr. J. Henderson and Mr. R. P. Worley. Mr. Henry Suter made most of the specific determinations of fossils, but a few are by Dr. J. Allan Thomson and others. Mr. H. S. Whitehorn, Assistant Topographer, is responsible for much of the topographic detail, and the maps are the work of Mr. G. E. Harris, Draughtsman to the Survey.

Though the greater part of the bulletin was written by myself, several important sections were compiled by Mr. Bartrum. Owing to the latter's resignation from the Geological Survey staff in January, 1913, the revision of the manuscripts and proofs fell to my lot. I am, therefore, entirely responsible for the form, and, in most cases, for the substance of all opinions expressed.

I have the honour to be,
Sir,
Your obedient servant,
P. G. MORGAN,
Director, New Zealand Geological Survey.

The Hon. W. Fraser,
Minister of Mines, Wellington.

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By Authority: John Mackay, Government Printer.

MAP OF
WESTPORT DIVISION
SHOWING SURVEY DISTRICTS

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BULLETIN No. 17 (NEW SERIES).

THE GEOLOGY AND MINERAL RESOURCES

OF THE

BULLER-MOKIHINUI SUBDIVISION,

WESTPORT DIVISION.

CHAPTER I.

GENERAL INFORMATION.

Introduction.

The Buller-Mokihinui Subdivision forms part of the Westport Division, which is situated on the west coast of the South Island of New Zealand, and is adjoined on the north by the Karamea, on the south by the North Westland Division. It lies wholly within Buller County, which is a portion of the old provincial district of Nelson, and includes the survey districts of Mokihinui, Ngakawau, Orikaka, Kawatiri, Steeples, and Waitakere, together with a small portion of Lyell Survey District. The subdivision is an irregularly shaped district with a length from north to south of forty-one miles, a width varying from four and a quarter to thirty-two miles, and a total area of approximately 590 square miles. Its surface is one of varied relief, a lowland strip near the coast being backed by high mountainous country, cleft by the gorges of several large streams, pre-eminent among which is the Buller or Kawatiri, the largest river on the west coast of the South Island. Although forest covers much of the region, the treeless barren areas known as "pakihis" form a conspicuous feature of the landscape, especially near Westport.

From an economic point of view the Buller-Mokihinui Subdivision is noted for its deposits of high-grade bituminous coal, which for man ears have been actively mined by the Westport and other coal companies. Brown coal and lignite also occur in quantity. During the past fifty years or so some millions of pounds' worth of gold have been won from rich surface gravels, but the alluvial-mining industry has now greatly declined, and the present gold-production is only a small fraction of that which characterized the palmy days of 1866 or the immediately succeeding years.

Among other natural resources of the subdivision are auriferous-quartz lodes, building-stones, cement-materials, brick-clays, and a few minerals of minor importance. A considerable amount of valuable timber still remains in the forests, but this asset is a diminishing quantity which will be almost exhausted before the close of another generation.

Early History.

In December, 1642, Abel Jansen Tasman, shortly after he had first sighted New Zealand, sailed northward along the coast of the subdivision. In his journal he remarks unflatteringly that it seemed a barren land.* More than a century later, Cook, sailing northward from Dusky Bay, encountered a severe storm when off the conspicuous point to which his predecessor had given the name of Clippingen Hoek, but which the great English navigator, in memory of his experience, renamed Cape Foulwind.

During the early part of the nineteenth century the west coast of the South Island was frequented by sealers, a party of whom is recorded as having been camped in 1836 on the islets off Cape Foulwind known as the Three Steeples.† Between 1845 and 1860 various explorers, including Charles Heaphy, Thomas Brunner, James Mackay, Alexander Mackay, and John Rochfort, traversed the coast-line and the Buller Valley. Gold, it is said, was first found by Rochfort's survey party at "Old Diggings," near Berlin's, in the year 1859. From this time onward search for gold on the banks of the Buller was more or less continuously made with some success. Attention having been turned to the coastal district, in a few years came the discoveries of rich alluvial gold at Charleston, Addison's, Giles Terrace, Fairdown, Mokihinui, &c. In 1859 and 1860 Rochfort and von Haast made discoveries of bituminous coal.‡ The mining of coal began about 1863, but was prosecuted with little vigour or success until 1880, when the Westport Colliery Company, which two years later was reconstructed under the title of the Westport Coal Company, succeeded in bringing coal to market. Since then coal-mining has become the chief industry of the subdivision, a position it will hold for many years to come.

Field-work.

Topographical field-work in the Buller-Mokihinui Subdivision began in January, 1911, under the control of Mr. H. S. Whitehorn, Assistant Topographer, and continued until June, 1913, with the exception of the winter months of 1911 and 1912. In all, about twenty-three months were occupied in obtaining topographical data. Geological field-work was concurrently carried out by one or both of the writers of this bulletin. The senior author was in the field for about fourteen months between January, 1911, and May, 1913, but a considerable portion of his time was occupied with other work not connected with the survey of the subdivision. During a few weeks in January and February, 1911, he was assisted by Dr. J. Henderson, and for about three months in the summer of 1911–12 by Mr. R. P. Worley, M.Sc. The junior author of this bulletin was in the field for some four months of the 1912–13 season.

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* T. M. Hocken: "Abel Tasman and his Journal." Trans., vol. xxviii, 1896, pp. 128–129.

† This name in its French form (Trois-Clochers) was probably first used by Dumont D'Urville (January, 1827). See S. P. Smith: "Captain Dumont D'Urville's Exploration of Tasman Bay in 1827." Trans. vol. xl, 1908, p. 419. The reference to the sealers will be found in "The Handbook of New Zealand Mines" (P. Galvin), pt. i, 1887, p. 95.

‡ The first recorded coal discovery was made by Heaphy and Brunner near the Waitakere in 1846. See Literature, p. 10, and Coal-mining, p. 31.

Except during the first few months of 1911, bad weather prevailed throughout the survey, and was the cause of much loss of time. Work was also retarded by a series of mishaps to members of the party, due chiefly to the rough nature of the country that had to be traversed.

Plan of conducting Work.

Field-work was based upon maps, drawn on a scale of 1 in. to 20 chains, supplied by the Lands and Survey Department, Nelson, and embodying all data that could be obtained from the available records. For a great part of the subdivision these maps, invaluable though they were as a foundation for subsequent work, lacked necessary detail, and numerous supplementary surveys were executed in order to furnish materials for a topographic map on which the geology could be accurately placed. Although a few of the smaller watercourses were merely pace-traversed, nearly all the numerous streams and tracks were surveyed by prismatic compass and chain. These traverses were checked to some extent by cross-bearings from a theodolite, which was also occasionally used as a tacheometer in open country. Rainy and cloudy weather, however, prevented full use of the theodolite being made, so that in some cases the heads of streams and other points obtained by compass-work are not so accurately fixed as is desirable.

Acknowledgments.

The assistance given by the Lands and Survey Department in connection with the topographical maps has already been mentioned. Without these maps accurate geological mapping would have been impossible until costly surveys had been made. All the analyses and assays appearing in this report, except a few expressly stated as derived from other sources, were made by Dr. J. S. Maclaurin, Dominion Analyst, and his staff, to whom the special thanks of the Geological Survey are due for the valuable nature of the chemical data supplied. Through the courtesy of mine-managers, land-surveyors, and others, much additional information of value was obtained. Among those who thus assisted may be mentioned Messrs. Frank Reed, I. A. James, J. Newton, F. H. Chamberlain, J. C. Brown, W. Dunn, A. G. Marshall, Thomas Thompson, R. A. Young, C. N. Greenland, H. Sharp, Julius Schadick, Sydney Fry, and J. Bradley.

Fauna and Flora.

The fauna of the Westport Subdivision resembles that of other parts of the west coast of the South Island, and need not be described at length. The weka (*Ocydromus australis*) is now everywhere scarce, but in the mountain-valleys the grey kiwi (*Apteryx oweni*) is comparatively plentiful. The call of the kakapo (*Stringops habroptilus*) was heard in the Ohikanui Valley, but the bird itself was not seen, and is evidently far from common. Other forms of bird life are moderately abundant in portions of the forested areas. The presence of numerous seals on the islets off Cape Foulwind known as The Steeples deserves mention. Among introduced animals the opossum is now becoming plentiful on the Paparoa Range. A few red deer may be found on the slopes of Mount Rochfort and near Addison's. Trout are to be seen in the main streams and most of their tributaries, but of more importance in its season is the inanga or native whitebait.

The forest flora of the Westport district resembles that of other parts of western Nelson, but the vegetation of the pakihis, whilst in most respects similar to that of swampy moorlands in other parts of Nelson and in Westland, presents several peculiarities. A few years ago Mr. W. Townson thoroughly explored the district from a botanical point of view,* and discovered a number of new species, most of which were described by Mr. T. F. Cheeseman. Since then the district has been visited by Dr. L. Cockayne and Dr. D. Petrie. Collections made by the senior writer of this bulletin have been examined by Mr. Cheeseman and by Dr. Petrie. As a result of all observations, between twenty-five and thirty plants, including two or three new species, have been added to the flora as listed by Townson.†

Previous Geological and Topographical Explorations and Surveys.

Few of the provincial papers, in which are generally to be obtained the best and in many cases the only accounts of the adventurous journeys of the early explorers, are accessible to the authors. The earliest exploration recorded in the available literature is that of Charles Heaphy and Thomas Brunner, surveyors employed by the New Zealand Land Company, who in 1846 made their way from Nelson to West Wanganui, and thence travelled along the coast to the Arahura River. Near the mouth of the Waitakere the explorers found coal (lignite). In 1847 Brunner revisited the district.

John Rochfort, a surveyor employed by the Nelson Provincial Government, in 1859 was at work on a survey of the Buller River. He had previously journeyed overland from Nelson to the mouth of the Grey River, whence he had made his way along the coast to where Westport now stands. As already mentioned, gold was discovered in the subdivision by his expedition. Rochfort found bituminous coal in the Waimangaroa Valley, and also recorded various facts of geological interest.

The first exploration by a geologist was that of Julius von Haast, who in 1860 followed James and Alexander Mackay's inland route from Nelson to the West Coast, and, after reaching the sea by way of the Grey Valley, returned to Nelson along the coast-line. His topographical and geological observations in the Buller district formed a basis for the work of Messrs. J. Burnett and J. Blackett, who in 1862 and 1863 respectively were sent by the Nelson Provincial Government to survey the coalfield discovered by von Haast between Mount Rochfort and Mount William. Their reports were of value in directing attention to the great possibilities of the Buller coalfield.

The main foundation of the geology of the coalfields was laid by Hector, who early in 1867 traversed the coast-line from south to north, and in subsequent years made further examinations of various portions of the coal-bearing areas. The results of his explorations were published in an "Abstract Report on the Progress of the Geological Survey of New Zealand" (1867), a "Report on the Coal-mines in the Western District of the Province of Nelson" (1872), and in various later reports.

In 1873 a complete investigation of the Buller coalfield planned by Sir James (then Dr.) Hector in conjunction with the Public Works Department was set in hand. W. M. Cooper made a detailed topographical survey of the greater part of the bituminous coal-bearing area, the result of which was embodied in a series of excellent maps published between 1875 and 1878. Reports upon the coal-outcrops, by R. B. Denniston, who was attached to Mr. Cooper's party as "coal-viewer," appeared in 1875 and 1877, and contain many valuable observations. Further reports by S. H. Cox, who partly supervised the operations of Cooper and Denniston, and paid two brief visits to the coalfield, were published in 1875 and 1876, in appendices to the Public Works Statements, and were reprinted in 1877 in the Geological Survey reports.

In the early part of 1874 Alexander McKay collected fossils in the Mokihinui district and at Cape Foulwind. He also made collections from the Miocene rocks near Inangahua Junction, and at Brighton, a few miles south of Charleston, both

* W. Townson: "On the Vegetation of the Westport District." Trans. vol. xxxix, 1907, pp. 380–433.
† See papers by D. Petrie and T. F. Cheeseman in Trans., vol. xlvi, 1914, pp. 21, 29–30, 33, 35, &c.

localities somewhat outside the boundaries of the subdivision. McKay's comments upon the geological relations of the rocks in and near the subdivision are most valuable.

From 1877 to 1911 very little geological work was done in the Buller-Mokihinui Subdivision, although Hector, and more especially McKay, made a number of brief visits to the district, and it is frequently mentioned in the reports of the last-named geologist. Other workers who have visited the subdivision and contributed to its geological literature are A. D. Dobson (1874, 1875), F. W. Hutton, and Dr. William H. Gaze.

Soil and Subsoil.

The character of the various soils in the Buller-Mokihinui Subdivision is everywhere determined by easily explainable geological factors. The river flats usually have a fairly fertile though light soil of some depth, formed mainly of silt underlain by uncemented gravel, which allows of good drainage. Near the coast are in places sandy tracts, which, if sufficiently drained, support, or formerly supported, a dense forest vegetation, and when cleared become good pasture land. Inland of the sandy belt, swamps, most of which carry a good deal of New Zealand flax (*Phormium tenax*), are a conspicuous feature, especially near Waimangaroa.

The lowland pakihis, with their sour and apparently barren soil, have a peaty surface, resting on a subsoil of hard iron-cemented gravel, with or without clayey layers. In all cases the result is the same: soil-drainage is practically wanting, and only a restricted range of plants can exist. Analyses show that pakihi soils need the addition of lime (or ground limestone) in order to liberate potash, which is present in fair quantity, but not in a form available for plant-food. The further addition of a fertilizer containing phosphoric acid is generally necessary. Although the pakihis present appreciable surface slopes the problem of their drainage has not yet been satisfactorily solved on economical lines. Recently experiments in the direction of breaking the subsoil with explosives have been made near Westport, and, it is thought, give promise of commercially successful results.*

Where Miocene rocks outcrop, as near Charleston and north of the Mokihinui, forest flourishes on a soil capable of being transformed into a good pasture land. This is especially the case with the areas immediately underlain by limestone. The marine mudstones forming the upper part of the bituminous coal-measures also give rise to a fairly good soil; but the grits and sandstones of a lower horizon lack the substances essential for the formation of a fertile soil, and therefore the areas directly underlain by them are barren in the extreme, bare rock forming the surface at many spots; elsewhere the soil is composed of a mixture of sand and peat, in which a peculiar assemblage of plants, similar to that of the lowland pakihis, finds root; and only in a few places does scrub or low bush appear. The greywackes and argillites that form the oldest rocks of the district do not, as a rule, afford by their decomposition a fertile soil, and the same remark may be made with even greater truth concerning the granites and quartz-porphyries that intrude the ancient sedimentaries. In places, however, alluvial fans composed mainly of greywacke gravel have been found worth

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* The following publications, among others, may be consulted for further information concerning pakihi soils:—

B. C. Aston: "Wire-basket Method of Testing Soils." Bulletin No. 2, Chemistry Division, N.Z. Department of Agriculture, 1907.
B. C. Aston, in Report of the Department of Agriculture, Chemistry Division, 1909, pp. 464–467.
B. C. Aston, in the *Journal of Agriculture*, vol. i, No. 1, 1910, p. 22.
G. de S. Baylis: "Treatment of Refractory Soils." *Journal of Agriculture*, vol. v, No. 1, 1912, pp. 71–74.
A. Macpherson: "Drainage by Explosives." *Journal of Agriculture*, vol. v, No. 2, 1912, pp. 126–133.
B. C. Aston: "Pakihi Lands." *Journal of Agriculture*, vol. vii, No. 3, 1913, pp. 295–300.

clearing and grassing. The value* of these fans depends largely upon the excellent drainage of their surfaces.

Climate.

The outstanding feature of the climate of the Buller-Mokihinui Subdivision is the heavy rainfall, which is spread very evenly over the year, and is the chief cause of the covering of dense bush spread over most of the area. Along the coast the average yearly rainfall is somewhat under 80 in., but on the mountains the precipitation is without doubt considerably greater. High winds are not so prevalent as in most other parts of New Zealand. The most common directions of the air-currents are from the north-west, the west, and the south-west, the last-named predominating. Except on the high country, the winter frosts are not severe. Snow very rarely falls near the sea-coast, and only occasionally in the Buller Valley; but there is a heavy winter and spring precipitation on the crest of the Paparoa Range and other high points. Fog is prevalent on the elevated country near Denniston and Millerton during the greater part of the year, though the winter season is usually the least objectionable in this respect.

The following table, kindly supplied by Mr. D. C. Bates, Government Meteorologist, shows the average monthly and yearly rainfall at Westport, Denniston, Reefton (a few miles south-east of the subdivision), and at Greymouth, which is a little over fifty miles south-south-west of Westport.

Mean Monthly and Average Rainfall in Inches.

Station.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual Rainfall.
Westport	6·92	4·22	6·29	6·50	6·51	7·65	6·39	6·19	7·02	6·83	6·48	6·80	77·80
Denniston	7·31	4·32	5·97	7·36	7·63	7·93	7·28	6·64	7·28	9·17	10·26	8·70	89·85
Reefton	5·72	2·90	6·19	6·68	6·22	9·21	5·74	7·89	8·60	8·08	7·53	6·62	81·38
Greymouth ..	9·12	5·95	9·71	8·68	8·32	9·06	7·81	7·62	8·02	10·70	8·82	9·10	102·91

These figures are founded on observations taken at Westport for twenty years, at Denniston for nine years, at Reefton for nine years, and at Greymouth for twenty-two years. Observations made at Karamea, a few miles north of the subdivision, for two years and three-quarters show that the rainfall there is decidedly less than at Westport, but owing to the shortness of the period the data obtained are nearly useless for comparative purposes, and at the request of Mr. Bates are therefore not published.

Inhabitants.

The principal centre of population in the subdivision is the Borough of Westport, which according to the census of 1911 had 4,729 inhabitants. Other centres are the townships of Denniston, 842; Burnett's Face, 627; Millerton, 708; Granity, 589; Waimangaroa, 362; Ngakawau (including Hector), 293; Seddonville, 426 (with St. Helens, 525); and Omau (Cape Foulwind), 203. Charleston, once a town with many thousands of inhabitants, is now a little village with a population of eighty, or, including the adjoining settlements, 201. Addison's is an even smaller hamlet. There is a scattered country population which cannot be exactly estimated. The total population of Buller County, together with the Borough of Westport, in 1911 was 11,447, including thirty-six Maoris. Of this number, over 10,500 were resident in the Buller-Mokihinui Subdivision.

Means of Communication.

The means of communication between the various parts of the Buller-Mokihinui Subdivision may be summarized as being on the whole good. From Westport a

Plate I.

Westport Coal Company's Rope Road between Denniston and Burnett's Face. Mount William seen faintly in Background. Barren Grits and Sandstones form the Foreground.

[*Frontispiece.*

Denniston in 1906. Slopes of Mount Frederick in Background, across the Deep Waimangaroa Gorge.

railway, owned jointly by the Government and the Westport Harbour Board, runs north-east to Seddonville (twenty-nine miles) and Mokihinui Mine (thirty-one miles), *en route* tapping the various coal-mines. Connection with the mines near Denniston is made by means of a short branch line from Waimangaroa Junction to Conn's Creek, where is the foot of the famous Denniston incline.

Ultimately Westport will be connected with the main railway system of the South Island, and with this intention a line has been constructed for six miles southward from the town to Te Kuha, at the entrance to the Buller Gorge, whence the formation has been carried for several miles through the gorge. When completed it will connect with the proposed Greymouth–Reefton–Nelson Railway* at Inangahua Junction.

The Westport Harbour Board, chiefly for the purpose of obtaining material for the harbour moles, has made a railway along the coast from Westport to Cape Foulwind. This line carries a considerable revenue-producing traffic in passengers, timber, and other goods.

Of the roads within the subdivision the coach-road through the Buller Gorge which connects with the Reefton–Nelson Road at Inangahua Junction, is the most important, since it affords the only route for wheeled traffic from Westport to other parts of the South Island. South-west from Westport a road connects with Charleston, and thence continues to the southern boundary of the subdivision, not far beyond which it becomes a bridle-track, ultimately reaching the Greymouth district. Northward a road has been made from Westport to Seddonville, with branches to Burnett's Face, *via* Denniston, and to Millerton. Near Seddonville a branch (the New Inland Road), which at the time of writing has not been quite completed for wheeled traffic, leads to Corbyvale, whence it connects with Karamea by way of Little Wanganui. The "Old Inland Road" to Little Wanganui is a horse-track, which follows the south bank of the Mokihinui from Seddonville to Rough-and-Tumble Creek, and thence, crossing the Mokihinui by means of a fine single-span bridge, continues up the Rough-and-Tumble Valley.†

From Mokihinui Mine a foot-track, known as the Mokihinui–Lyell Track, has been constructed in a southerly direction for over seventeen miles. This track, orginally a good one for the greater part of its course, is so little used that much work had to be done on it by the Geological Survey party in order to render it suitable for the transport of food and tents. At its southern end it meets a far worse cross-track, with the title of "Buller County Council Prospecting Track," which, beginning as an extension of the road from Burnett's Face to "Kiwi Compressor," follows the Waimangaroa Valley for about two miles, and then turns eastward. After crossing the Mount William Range, the Mackley River, and a considerable extent of broken country, where it is usually very difficult to follow, the track reaches the Buller River at the mouth of Pensini Creek, or, more correctly, reaches the north bank of Pensini Creek some distance from the Buller. Its total length is about thirteen miles.

Various roads and tracks which are shown on the maps need not be mentioned here. In connection with the work of the Geological Survey, several old tracks, including those mentioned above, were cleaned out, and a number of blazed lines cut.

The chief means of external communication is the port of Westport. The mouth of the Buller River has been so much improved by moles and other works that it is now the best harbour (the Otago Sounds excepted) on the west coast of the South Island. The average depth of water on the bar at high water, once only 10 ft. or 11 ft., is now about 23 ft., and at spring tides may reach 27 ft.

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* The middle portion of this railway (between Inangahua Junction and Glenhope) is not constructed.
† See N.Z.G.S. Bull. No. 11 (Mount Radiant), 1910, p. 5.

The entrance is sheltered from the prevailing south-westerly winds by Cape Foulwind and The Steeples, but it is exposed to north-westerlies. The following figures for the years 1910 to 1914, in part taken from departmental reports, and in part specially supplied by the Westport Harbour Board, will give some idea of the importance of the harbour:—

	1910.	1911.	1912.	1913.	1914.
Revenue of Harbour Board ..	£118,964	£91,190	£101,584	£96,558	£95,808
Expenditure	£80,270	£71,946	£122,061	£112,682	..
Coal exported (tons)	831,115	770,410	797,460	637,502	790,040
Coke exported (tons)	..	..	1,656	1,253	1,838
Timber exported (super. ft.) ..	..	..	..	1,467,938	1,415,021
Steamers visiting port	1,217	1,116	1,167	934	984
Sailing-vessels visiting port ..	10	9	8	14	11
Aggregate tonnage	711,881	711,881	691,614	523,362	601,214
Average depth of water on bar at high tide	23 ft. 1 in.	24 ft. 3 in.	23 ft. 6 in.	23 ft. 5 in.	22 ft. 9 in.
Average depth of water in river at high tide	29 ft. 9 in.	25 ft. 1 in.	25 ft. 6 in.	26 ft. 7 in.	26 ft. 0 in.

The approximate rise and fall of the tide varies from 6 ft. 6 in. at neap tides to 9 ft. 6 in. at spring tides.

In the early days of the Charleston goldfield Constant Bay was extensively used as a port by small vessels, the usual plan being to beach them at high water. The mouth of the Nile or Waitakere River is occasionally utilized as a harbour, but only very small vessels, and these at irregular intervals, can cross the bar, which is sometimes almost dry at low water. Many years ago some coal was exported in small steamers which managed to enter the mouth of the Ngakawau. More suitable as a harbour is the Mokihinui River mouth, which at irregular intervals was visited by shipping for many years. It is said that there is sometimes 18 ft. of water on the bar at high water, but occasionally the depth is so little that at low tide the bar can be forded. Since the wreck of the s.s. "Lawrence" in 1891 there is no record of the Mokihinui River having been entered by any vessel other than open boats.

Scenery.

The scenery of the Westport district, with the exception of the Buller Gorge, is singularly unappreciated and unknown. The chief reasons for this being the case are the lack of enthusiasm of the inhabitants and the uncertainty of the climate, for whilst few districts can boast such perfect days when the sun does shine, few become so frequently and gloomily immersed in all-pervading rain.

Within easy reach of Westport and the other centres of population is some of the most fascinating mountain scenery it is possible to desire; yet not many enthusiasts are found to climb the 4,000 ft. necessary to obtain from the top of almost any peak of the Paparoa Range one of the most captivating panoramas of bizarre rock-peaks that can be found in New Zealand or elsewhere.

Any one who thoroughly knows the scenery of the Westport district will readily admit that even the far-famed Buller Gorge has overshadowing rivals that, were they equally accessible, would be amongst the most noted beauty-spots of New Zealand. Such a rival is the Mokihinui Gorge. An easy six-mile walk or ride from Seddonville brings one to where the swiftly flowing Mokihinui River cleaves the granite mountains in a wonderful gorge, the walls of which are mirrored on the surface of deep pools, whilst a fine bridge, spanning the river over 80 ft. above the surface of the water, adds an additional element of picturesqueness to the scene. To those who have heard the history of gold-mining in the locality this scene is given further romance by the thought of the Trojans of the "seventies" and "eighties" who, lured by the gleam of gold, barged mining machinery and stores up many miles of this gorge amidst ugly rocks and rapids—a feat incredible to one unfamiliar with the resource and indomitable determination of these pioneers.

Other localities in the subdivision rendered noteworthy by reason of their scenery are the Ngakawau and Waimangaroa gorges and the sea-coast north of the Mokihinui River, whilst the caves and the picturesque gorge of the Fox River near Brighton, a few miles beyond the southern boundary of the subdivision, are becoming widely known for their beauty.

Primary Industries other than Mining.

(1.) *Timber.*

There are about a dozen sawmills in the subdivision, most of which are constantly at work, whilst the others are intermittently operated. The chief timber-tree converted is the rimu or red-pine (*Dacrydium cupressinum*), and next in importance is yellow silver-pine (*Dacrydium intermedium*), which, together with the much less common silver-pine (*Dacrydium Colensoi*) is of great value for railway-sleepers. Other trees milled to a small extent are black-birch, also called "brown-birch"—really a beech (*Fagus fusca*) —white-pine or kahikatea (*Podocarpus dacrydioides*), and one or two others. The principal trees used for mine-timbering are the birches or beeches (*Fagus fusca, F. Menziesii*, and *F. Solandri*), together with rimu, kamahi (*Weinmannia racemosa*), and some others.

(2.) *Agricultural and Grazing Industries.*

Agriculture proper is in a backward state in the Buller-Mokihinui Subdivision, but the clearing and grassing of land for grazing purposes is proceeding at a fairly rapid rate, especially near Seddonville, Birchfield, and Charleston. Nowhere, however, is there any extensive area artificially cleared. The dairying industry has made some progress, there being thriving butter-factories at Birchfield and Charleston. The cattle and sheep-farming branches are so little developed that the graziers are unable to supply the local market, a fact clearly demonstrated during the labour strike of 1913.

(3.) *Miscellaneous Industries utilizing Primary Products.*

There are two mills for the manufacture of New Zealand flax-fibre in the subdivision, one at Birchfield, the other at Waimangaroa. A brickmaking plant is in operation at Waimangaroa Village, and a lime-kiln is intermittently operated near Cape Foulwind. Of considerable importance are the quarries which have been opened by the Westport Harbour Board at Cape Foulwind in order to supply stone for the moles at the mouth of the Buller River. In the spring months sufficient whitebait is netted to supply the local demand and, in addition, to support a canning-factory for a few weeks.

Literature.

The list of literature here given includes all the more important publications relating to the geology of the Buller-Mokihinui Subdivision, but cannot be regarded as complete, the writers having been unable to obtain access to some of the old provincial papers of Nelson and other early literature. A few references deemed of little importance are purposely omitted, and one or two of greater value may have been accidentally overlooked.

The following abbreviations are used :—

Trans. : Transactions of the New Zealand Institute.

Rep. G.S. : Reports of the Geological Survey of New Zealand (previous to 1905).

Mines Reports : Papers and Reports referring to Minerals and Mining (the annual volume published by the New Zealand Mines Department).

Mines Record : New Zealand Mines Record.

A capital letter followed by a figure (thus, C.–3) refers to a New Zealand parliamentary paper. The dates given refer to the dates of publication of the several papers.

1847. Heaphy, Charles. "Notes of an Expedition to Kawatiri and Araura [Arahura] on the Western Coast of the Middle Island." *The New Zealand Journal*, vol. vii, 1847, Nos. 191 and 192, pp. 104–7, and 115–18. (See Carter Collection, N.Z. Institute Library, Dominion Museum.) During 1846 Messrs. Heaphy and Brunner, accompanied by two Maoris, traversed the coast-line from West Wanganui to the Arahura River. On the 28th April they forded the Mokihinui River at its mouth, and on the 30th reached the Buller (Kawatiri) River. On the 14th May, coal (lignite) was observed in the vicinity of the Waitakere River. Various geological observations relating to the coast-line are recorded. *The New Zealand Journal*, so far as the search made extended, does not contain any particulars of the return journey.

1849. "Mr. Brunner's Late Exploring Expedition." *The New Zealand Journal*, vol. ix, 1849, Nos. 244 and 254, pp. 80–82, 197–98. (See "Carter Collection," N.Z. Institute Library, Dominion Museum.) During the years 1846–48, in an expedition lasting 80 weeks, Brunner forced his way from Nelson down the Buller River to its mouth, where he arrived on 4th June, 1847. He then travelled down the coast to the Paringa River (South Westland), retraced his steps to the mouth of the Grey River, and returned to Nelson via the Grey and Buller valleys, &c. Brunner's diary was published in the *Nelson Examiner*, and reprinted with considerable omissions as above.

1851. Brunner, Thomas. "Journal of an Expedition to explore the Interior of the Middle Island of New Zealand." *Journal of the Royal Geographical Society*, vol. xx, 1851, pp. 344–378. This is Brunner's diary in full, mentioned above. A copy is available in the "Carter Collection" (Pamphlets, vol. xxiii.)

1860. Tatton, J. W. : "Report on Analysis of West Coast Coal." *Nelson Gazette*, vol. viii, No. 8, May 30, 1860, p. 37. This is the analysis quoted by von Haast in his report of 1861, p. 114.

1861. Haast, J. von : "Report of a Topographical and Geological Exploration of the Western Districts of the Nelson Province." On p. 56 Haast mentions his discovery of coal at Coalbrookdale. On pp. 111 *et seq.* he notes "Cretaceous" limestone at Cape Foulwind and friction-breccia at Ngakawau and (erroneously) states that in some places—*e.g.*, to the north of Mount Frederick—the coal strata are intruded by granite with formation of interesting contact rocks. He estimates the thickness of "Carboniferous" beds from Mount Rochfort to the Waimangaroa as 3,500 ft.

1862. Rochfort, John : "Journal of Two Expeditions to the West Coast of the Middle Island of New Zealand in 1859." *Journal of the Royal Geographical Society*, vol. xxxii.

1862. Burnett, J.: "Reports of the Grey Coalfield north of the Buller River." *Nelson Gazette*, vol. x, No. 21, pp. 73–83. This report gives the result of the first detailed examination of the Coalbrookdale plateau, whence Burnett, allowing a large factor of safety, estimated that 72,600,000 tons of coal could be extracted. Gold workings in the Waimangaroa River are recorded. Many useful geological notes are given in the course of the report.

1863. Burnett, J.: "Report on that Part of the Grey Coalfields situated at Mokihinui." *Nelson Gazette*, vol. xi, April 20, No. 8, pp. 21–24. Burnett examined the known outcrop of coal at the sandstone gorge of the Mokihinui River, and also found broken coal in a gully on the other side of the river. He gives a fairly comprehensive account of the geology of the district, and states that a mining company was at work in the district. In this connection the names of Messrs. Batty and Hunter are mentioned.

1863. Burnett, J.: "Report on Part of the Grey Coalfield north of the Buller River." *Nelson Gazette*, vol. xi, April 20, No. 8, pp. 24–29. This report gives an account of further detailed work by Burnett on the coalfield in the vicinity of Mount Rochfort and Waimangaroa. The writer remarks on the extraordinary chasm of the Waimangaroa Gorge.

1863. Blackett, J.: "Report on the Buller and Grey Coalfields." *Nelson Gazette*, vol. xi, May 12, No. 14. This report deals chiefly with questions concerning the means of transport of the coal, but contains also some geological details.

1864. Hochstetter, F. von: "Lecture on the Geology of the Province of Nelson." Auckland, 1864. Hochstetter remarks that the terraces of the Buller River prove an elevation of the land of about 2,000 ft. since Tertiary times.

1866. Hector, James: "First General Report on the Coal-deposits of New Zealand." Rep. G.S. No. 1 (vol. i). Hector states that the coal available in the Westport district has been estimated at 200,000,000 tons, and also quotes the results of trials made at Woolwich Dockyard.

1867. Hector, James: "Abstract Report on the Progress of the Geological Survey of New Zealand during 1866–67." This report, furnished to the Colonial Secretary, was republished with sections in a slightly different form in 1868 (see below).

1867. Hochstetter, F., von: "New Zealand." Hochstetter thinks that the Pakawau, Buller, and Grey River coals are probably of Mesozoic age.

1868. Hector, James: "Abstract Report on the Progress of the Geological Survey of New Zealand during 1866–67." Rep. G.S. No. 4. On pp. 22–24 Hector gives details of the Buller coalfield, and mentions that a mine was opened at Mokihinui some years previously. He notes faults up to 1,200 ft. in throw. On p. 32 the chemical nature of some "lode" rocks at Waimangaroa is compared with that of auriferous rocks at Coromandel, Baton River, Thames Valley, and elsewhere. These lodes are thought by Hector to owe their origin to thermal waters. He considers that the source of the alluvial gold near Westport is in the upper terraces of the Buller River, and that the gold-leads south of the Grey River were deposited by an ancient river now represented by a north-east and a south-west depression and crossed by the present drainage-channels.

1870. Hector, James: "On Mining in New Zealand." Trans., vol. ii, pp. 361–84. On p. 369 there is a brief mention of gold in quartz at Waimangaroa, and on pp. 379–80 of the Buller coalfield.

1871. "Joint Committee on Colonial Industries (Report of)." H.-7. On p. 17 Eugene O'Conor refers to the discovery of coal near the Buller River, about five miles in a direct line from Westport.

1872. Hector, James: "On the Remains of a Gigantic Penguin (*Palæeudyptes antarcticus*, Huxley) from the Tertiary Rock on the West Coast of Nelson." Trans., vol. iv, pp. 341–46. (See also Trans., vols. ii and v.) This paper contains some general remarks on the coal-bearing strata of the west coast of the South Island.

1872. Hector, James: "Report on the Coal-mines in the Western District of the Province of Nelson." Rep. G.S. during 1871–72, No. 7, pp. 129–41. This report deals particularly with the sequence of strata in the coalfields of the Westport district. Hector remarks that coal occurs in trough-like areas due largely to inequalities of the surface on which the coal strata were deposited, and considers that there is only one seam at Coalbrookdale. On pp. 134 and 138 are maps of the Mount Rochfort coalfield and of the Ngakawau River respectively.

1872. Hector, James: "General Report on the Coals of New Zealand." Rep. G.S. during 1871–72, No. 7, pp. 172-81. This report includes analyses of eleven samples of Buller coals collected by the Geological Survey.

1872. Hutton, F. W.: "Synopsis of the Younger Formations of New Zealand." Rep. G.S. during 1871–72, No. 7, pp. 182–84. Mokihinui is mentioned as one of the localities where the Greymouth group of the Waipara Formation occurs. The synopsis in a slightly altered form appeared later in the *Quarterly Journal of the Geological Society*, vol. xxix, 1873, p. 372.

1872. "Papers relating to the Development of Coal-mines, &c." D.-3. A preliminary report by Dr. Hector on coal-areas in south-west Nelson, and maps of Mount Rochfort and Ngakawau River coalfields, appear in this parliamentary paper.

1873. "The Coalfields of New Zealand (Reports on)." E.-10. Amongst other pertinent material is a "Memorandum relative to Mount Rochfort district," by Dr. Hector. On p. 4 are analyses of some Westport coals.

1873. "The Buller Coalfields (Reports relative to)." E.-10A. The same geological matter appears as in E.-10, 1873, above.

1873. "Colonial Industries (Report of the Select Committee on)." I.-4. Contains, *inter alia*, a memorandum by Dr. Hector relative to the iron-ores of New Zealand. This has a reference to the ironsands of the Lower Buller River, which are shown by an attached analysis to be highly titaniferous. The report also gives some information concerning Mount Rochfort coalfield.

1873. Hutton, F. W.: "Catalogue of the Tertiary Mollusca and Echinodermata of New Zealand." Wellingon, 1873. Many of the species described were collected at Brighton, a district contiguous to the Buller-Mokihinui Subdivision.

1873. Hutton, F. W.: "Synopsis of the Younger Formations of New Zealand." Quar. Jour. Geol. Soc., vol. xxix, p. 372. Hutton classes the Lower Buller River coals (probably the brown coals of Inangahua Junction) as of Lower Eocene age, and those of the Mokihinui and Mount Rochfort coalfields he includes in his Cretaceous Danian (or Waipara) Formation.

1874. "Public Works Statement." E.-3. Appendix E contains "Report on the Coalfields of New Zealand," by Dr. Hector. In this is embraced a report by W. M. Cooper on the topographical survey of the Buller coalfield, which he began on the 14th November, 1873.

1874. Dobson, A. D.: "Notes on the Glacial Period." Trans., vol. vi, pp. 294–97. The writer considers that the raised beaches on the west coast were formed during the period of elevation that, in his opinion, caused the glacial extension. In support of this view he states that débris brought from Mount Rochfort by glacial agencies overlies the auriferous beach drifts on the slopes of that mountain.

1874. Hector, James: "New Zealand Geological Sketch-map, constructed from Official Surveys and the Explorations of Dr. von Hochstetter, Dr. J. von Haast, and Others." Wellington, 1874.

1874. Hutton, F. W.: "Table of the Sedimentary Rocks of New Zealand." Geol. Mag., Nov., 1874, p. 515.

1875. Dobson, A. D.: "On the Date of the Glacial Period: a Comparison of the Views represented in Papers published in the Transactions of the New Zealand Institute, vols. v and vi." Trans., vol. vii, pp. 440-46. Dobson states that he knows of no raised beaches of later age than the date of the glacial extension, and that the highest gold-lead in the auriferous beach drift is at Dawson's Terrace (? near Charleston) at a height of 400 ft.

1875. "Public Works Statement." E–1. Appendix I, p. 88, contains a "Report on Buller Coalfield, by the Assistant Geologist" (S. H. Cox). This appears later in Rep. G.S. during 1874–76, No. 9, 1877, pp. 17–25.

1875. "Topographical Survey of Buller Coalfield (Report on)." E.–9. Interim reports by Messrs. Cooper and Denniston on their survey of the coalfield are published in this paper.

1876. "Public Works Statement." E.–1. Appendix I, pp. 86–93, comprises a "Report on Buller Coalfield, by the Assistant Geologist" (S. H. Cox). This report of Cox's appeared later in Rep. G.S. during 1874–76, No. 9, pp. 106–19.

1876. "Westport Colliery Reserve Commission, Report of." A.–3. Maps of the coalfield are given on p. 131.

1877. "Public Works Statement." E.–1. In Appendix F is a "Report on Coal Explorations conducted by the Geological Survey Department, 1876–77," which was furnished by Dr. Hector, and contains an estimate of the available coal in part of the Buller coalfield. (See "Progress Report," Rep. G.S. during 1876–77, No. 9.)

1877. Hector, James: "Progress Report." Rep. G.S. during 1873–74, No. 8. Pp. iii to v deal partly with the Mount Rochfort coalfield. Hector states that the main seam is trough-shaped, thinning towards the margins, and broken by several transverse faults. Opposite p. iv is a map of Ngakawau coalfield.

1877. Cooper, W. M.: "Maps of the Buller Coalfield to illustrate Reports by Mr. Cox and Mr. Denniston." Accompanied Rep. G.S. during 1874–76, No. 9, 1877. These excellent maps are of great value to the miner and the student of the geology of the Buller coalfield. Unfortunately, copies are now very scarce. Several other maps dealing with the topography of the Ngakawau portion of the district were prepared by A. Koch from Cooper's traverses, and published by the Public Works Department.

1877. McKay, Alex.: "Reports relative to collections of Fossils made on the West Coast District, South Island." Rep. G.S. during 1873–74, No. 8, pp. 74–115. McKay gives fairly full geological notes of the localities in which he collected fossils. Pp. 102–115 deal with the Buller district. In the Buller Gorge McKay considers that there is an unconformity between a sequence of lower brown sandstones and conglomerates and the upper coal and overlying calcareous beds. He notes the granite breccia along the coast north of the Mokihinui River.

1877. Hector, James: "Progress Report." Rep. G.S. during 1874–76, No. 9. In a few remarks relative to the coalfields of New Zealand, Hector states that large oysters are found in the sandstone overlying the upper seam of the Buller coalfield in the Orikaka (Blackburn) Valley, and also that 100,000,000 tons of available coal have been proved by the surveys of Cooper and Denniston on the Buller coalfield between Westport and Ngakawau.

1877. Cox, S. H.: "Report on Survey of Buller coalfield." Rep. G.S. during 1874–76, No. 9, pp. 17–25. This report is upon part of the area surveyed by Cooper and Denniston. Coal-analyses are given on p. 25. Cox is inclined to think that the brown coals of the North Island are of the same age as the South Island bituminous coals.

1877. McKay, Alex.: "Report on Weka Pass and Buller Districts." Rep. G.S. during 1874–76, No. 9, pp. 36–42. A short note is given in this report on the sequence and correlation of the beds at Inangahua Junction, but the only direct reference to rocks within the Buller-Mokihinui Subdivision is a mention of "nummulitic" limestone "within two miles of Lyell."

1877. Cox, S. H.: "Report on Survey of Buller Coalfield." Rep. G.S. during 1874–76, No. 9, 106–119. This is a report on the completed survey of Cooper and Denniston: it contains a number of detailed sections quoted from Denniston, and, opposite p. 112, various maps and sections.

1877. Denniston, R. B.: "Detailed Notes on the Buller Coalfield." Rep. G.S. during 1874–76, No. 9, pp. 121–170. Denniston here gives in elaborate detail the results of his painstaking work in examining and mapping the coal-outcrops during the course of the detailed survey by Cooper and himself of the Buller coalfield. A map showing the coal-areas faces p. 170.

1877. Hector, James: "Progress Report." Rep. G.S. during 1876–77, No. 10, and also in E.–1, 1877, p. 100. On pp. iii to v is a table of formations, and pp. xv to xvi deal with the Buller coalfield, where between Westport and Ngakawau Hector estimates that there are 105,534,000 tons of workable coal.

1878. "Public Works Statement." E.–1. Appendix M, pp. 82–92, consists of a "Report on Coal Explorations and Inspection of Mines, conducted by the Geological Survey Department during 1877–78," prepared by Dr. Hector. It includes a report by S. H. Cox on the Wellington Colliery at Waimangaroa (see also below).

1878. Hector, James: "On the Relative Ages of the Australian, Tasmanian, and New Zealand coalfields." (Abstract.) Trans., vol. x, p. 533.

1878. Hector, James: "Progress Report." Rep. G.S. during 1877–78, No. 11. On p. ii the Wellington Mine is mentioned in the list of collieries examined.

1878. Cox, S. H.: "Report on the Coal-mines of New Zealand inspected during the Past Year." Rep. G.S. during 1877–78, No. 11, pp. 160–79. On pp. 174–75 is a report on the Wellington Mine, the only colliery then working in the Westport district.

1879. Hector, James: "On the Fossil Flora of New Zealand." (Abstract.) Trans., vol. xi, pp. 536–37. This paper contains brief reference to the flora of the coal-bearing "Cretaceous" formation.

1879. Hector, James: "Handbook of New Zealand." This book was issued for distribution at the Sydney International Exhibition, 1879. A second edition was published in 1880 (Melbourne Exhibition), a third in 1883, and a fourth in 1886 (Indian and Colonial Exhibition). There are brief references to various features of the geology of the Westport district on pp. 21–50.

1879. Hector, James: "Progress Report." Rep. G.S. during 1878–79, No. 12. A *résumé* of New Zealand stratigraphy is given in connection with remarks on the geology of the North Otago District (pp. 31–32), and on p. 41 is a table showing the mines inspected, with the outputs for each.

1879. Haast, J. von: "Geology of Canterbury and Westland." In this book, which has many useful references to the general geology of New Zealand, one of the few direct references to the Buller district is on p. 451, where the author considers that the west coast bituminous coals are coeval with the coals on the east side of the South Island, but have been subjected to abysso-dynamic agencies that have not operated on the east coast.

1880. Hector, James: "On the Geological Formations of New Zealand compared with those of Australia." Trans. Royal Society of N.S.W., vol. xiii, p. 65. There is some detail given of the "Cretaceo-Tertiary" brown coals of the west coast and of the underlying bituminous measures of "Lower Greensand" age. A table of formations is included. An extract from this paper appears in Rep. G.S. during 1879–80, No. 13, pp. ii to iv (Progress Report), 1881.

1881. Hector, James: "On the Distribution of Auriferous Cements in New Zealand." (Abstract.). Trans., vol. xiii, p. 429. Several statements as to the origin of the gold-bearing gravels are made in this report.

1882. Cox, S. H.: "Notes on the Mineralogy of New Zealand." Trans., vol. xiv, pp. 418–50. Antimony-ore (stibnite) is reported from the Westport district.

1882. "Index of Fossiliferous Localities in New Zealand (with Table of Fossiliferous Formations in New Zealand.)" Rep. G.S. during 1881, No. 14, Appendix, pp. 118–128. In this index the fossils are listed according to their Museum numbers, and the locality of each is appended.

1882. "Westport Coal Committee (Report of)." I.–6. This report deals mainly with the Westport Harbour, but there is also discussion of the quality and tonnage of the available coal in the Westport district.

1882 (about). Metcalf, T. J.: "A Ramble through the Inangahua, Lyell, and Collingwood Reefs." A newspaper reporter's account of the quartz-mining fields in the early "eighties" of last century.

1883. Cox, S. H.: "Notes on the Mineralogy of New Zealand." Trans., vol. xv, pp. 361–409. On p. 367 is an analysis of "brown coal" from Charleston, on p. 370 that of a "pitch coal" from the Buller Valley, and on p. 373 are two average analyses of the Westport bituminous coal. Muscovite from Charleston is mentioned on p. 404, and various other minerals occurring in the Buller-Mokihinui Subdivision are indefinitely recorded as found on the west coast.

1883. McKay, Alex.: "On the Geology of the Reefton District, Inangahua County." Rep. G.S. during 1882, No. 15, pp. 91–153. On pp. 142–44 McKay discusses the Hawk's Crag breccias and their source. On p. 150 and elsewhere there are various other references to the geology of the Westport district.

1883. Hector, James: "Progress Report." Rep. G.S. during 1882, No. 15. On p. 28 Hector mentions the probability of overlap in Cretaceoüs and Cretaceo-Tertiary beds. He also notes the extension of the coalbeds from the Inangahua Valley into the Mokihinui country.

1884. Hector, James: "Progress Report." Rep. G.S. during 1882, No. 16. On pp. xii to xiv is a table of the sedimentary rocks of New Zealand. There is a reference to the "Great Breccia" of the Buller district, to which is assigned a Lower Greensand age.

1885 Hutton, F. W.: "Sketch of the Geology of New Zealand." Quar. Jour. Geol. Soc. vol. xli, p. 191. On p. 204 *et seq.* Hutton deals with his Waipara System, in which he includes the Buller bituminous coals, resting on rocks considered by him to belong to the "Maitai" Series. The Cape Foulwind limestone and its southern continuation, along with much of the brown coal of the Buller Valley, he classes in his Oamaru System, a view supported by the writers of the present bulletin (see Chapter V).

1885. Binns, G. J.: "Coal-mining in New Zealand." Trans. North of England Inst. Min. Eng., vol. xxxv, pp. 175–251.

1886. Gordon, H. A.: "Outline History of the Coal, Gold, and other Known Mineral Resources of New Zealand." Mines Report, 1886. (Not seen.)

1886. Haast, J. von.: "The Mineral Resources of New Zealand." *Austr. Times and Anglo-New-Zealander*, Supp. 1, Aug. 13, 1886. (Not seen.)

1886. Haast, J. von: "On the Character and Age of the New Zealand Coalfields." Rep. Brit. Ass. Adv. Science, 1886, p. 643. Von Haast notes that according to Ettingshausen's identifications of the fossil flora the bituminous coals must be placed in the Cretaceous.

1886. Hector, James: "Detailed Catalogue and Guide to the Geological Exhibits, New Zealand Court, Indian and Colonial Exhibition, 1886."

1886. Hector, James: "Outline of New Zealand Geology." This pamphlet formed the second part of the special catalogue of the geological exhibits sent to the Indian and Colonial Exhibition, London. In it are various references to the geology of the Westport district, particularly with respect to the coal-bearing series.

1887. "Index to Fossiliferous Localities in New Zealand." Rep. G.S. during 1886–87, No. 18, Appendix, pp. 255–70.

1887. Hector, James: "Progress Report." Rep. G.S. during 1886–87, No. 18. On p. xxxiv Hector has a few notes concerning the period to which the bituminous coals of the West Coast belong.

1887. Hector, James: "On the Mokihinui Coalfield." Rep. G.S. during 1886–87, No. 18, pp. 156–60. This short report does not discuss the general geology of the field at any length. It is stated that two seams of coal have been proved in the district, and that the probable available coal there exceeds 3,000,000 tons. Two maps are appended to the report.

1887. McKay, Alex.: "On the Mokihinui Coalfield." Rep. G.S. during 1886–87, No. 18, pp. 161–67. McKay gives full details of the coal-outcrops, and his report in this connection is useful.

1887. Ettingshausen, Constantin von: "Beitrage zur Kenntniss der fossilen Flora Neuseelands." Denkschriften der Mathematisch-Naturwissenschaftlichen Classe der Kaiserlichen Akademie der Wissenschaften (Vienna), Band liii. See also Trans., vol. xxiii, 1891, pp. 237–310, and Trans., vol. xix, 1887, pp. 450–51. Although none of the specimens described by the author were collected in the Westport district, yet their derivation from coal-measures of identical age with those in the subdivision compels consideration of this paper.

1887. Galvin, P.: "The Handbook of New Zealand Mines." On pp. 211–13 of pt. i is given the history of the discovery of gold in the Buller district, and on pp. 214–26 is general information relative to gold occurrences in the Buller-Mokihinui Subdivision. On p. 227 is a reference to the New Creek diggings. Amongst the minerals reported from the subdivision are copper-ore, stream-tin, manganese-ore, and alum shale. An account of the Mokihinui and Coalbrookdale coal-mines is given on pp. 22–24, pt. ii.

1888. Hector, James: "Progress Report." Rep. G.S. during 1887–88, No. 19. Notes relative to the economic value of New Zealand coals, together with several analyses, are given on pages xxx to xxxii.

1888. Gaze, W. H.: "An Introduction to Analytical Pyrology." Contains references to minerals found in the Westport district.

1889. Park, James: "On the Extent and Duration of Workable Coal in New Zealand." Trans., vol. xxi, pp. 325–31. In this important paper there are various remarks on the West Coast bituminous coals in general, and also estimates of the workable coal in the several districts.

1889. "Westland Coalfields Committee (Report of)." I.–6.

1889. Hutton, F. W.: "The Eruptive Rocks of New Zealand." Jour. and Proc. Roy. Soc. of N.S.W., vol. xxiii, pp. 102–56. On pp. 112–28 are descriptions of various rocks, chiefly granites, from the Westport district.

1890. Hutton, F. W.: "Description of some Eruptive Rocks from the Neighbourhood of Westport, New Zealand." Trans. Geol. Soc. of Australasia, vol. i, pt. iv, pp. 106–11.

1890. Hutton, F. W.: "On the Relative Ages of the New Zealand Coalfields." Trans., vol. xxii, pp. 377–87. Hutton ably reviews the evidence for the ages of the various coalfields of New Zealand, and considers that they belong to four distinct series, to the oldest of which—the Amuri—the Westport bituminous coals belong.

1890. Hutton, F. W.: "Note on the Geology of the Country about Lyell." Trans., vol. xxii, pp. 387–90. A few petrographical references concern the rocks of the Buller Gorge.

1890. Hector, James: "Progress Report." Rep. G.S. during 1888–89, No. 20. On pp. xxii to xxiii Hector specifically defines "evaporative power," and compares Westport and Greymouth coals with Newcastle coal. Page xxvii contains a table showing areas and tonnages of coal.

1891. Ettingshausen, Constantin von: "Contributions to the Knowledge of the Fossil Flora of New Zealand." Trans., vol. xxiii, pp. 237–310. This is a translation by C. Juhl of von Ettingshausen's paper of 1887.

1892. McKay, Alex.: "On the Geology of Marlborough and South-east Nelson." Part II. Rep. G.S. during 1890–91, No. 21, pp. 1–28. This important paper deals principally with the major fault-lines of New Zealand, and contains references to several fractures in the Buller district, particularly to the Lower Buller or Kongahu fault. A map showing fault-lines faces p. 1.

1892. Hector, James: "Progress Report." Rep. G.S. during 1890–91, No. 21. On pp. xxxiii to xli, under the heading of "Buller Coalfield," Hector gives many important facts about the geology of the Westport district, and criticizes Hutton's paper of 1889 "On the Relative Ages of the New Zealand Coalfields" (Trans., vol. xxii, pp. 377–87).

1892. McKay, Alex.: "On the Mokihinui Coal Company's Property, Coal Creek, Mokihinui." Rep. G.S. during 1890–91, No. 21, pp. 86–97. A history of the coalfield is given, together with the sequence of the strata, some mention of fossils from Chasm Creek, and a number of analyses of the coal.

1892. Hector, James: "Minerals of New Zealand." (Revised from Trans. Aust. Assn. Adv. Science, vol. ii, p. 269.) Rep. G.S. during 1890–91, No. 21, Appendix, pp. 105–20. (See also *Mines Record*, vol. iii, 1899–1900, pp. 256–63.) The Charleston mica is mentioned on p. 114, and on p. 108 coal-analyses are given.

1892. "Index of Fossiliferous Localities in New Zealand." Rep. G.S. during 1890–91, No. 21, Appendix, pp. 120-45. Attached to this list of localities of various fossils in the Dominion Museum is a table of the fossiliferous formations in New Zealand. Several fossils from the Westport district are included in the index. There is also an "Index to Fossiliferous Localities according to the Counties in which they occur" (Appendix, pp. 146–78), and on p. 149 are various remarks relative to the formations and fossils of the Buller County.

1892. McKay, Alex.: "On the New Cardiff Coal Property." Rep. G.S. during 1890–91, No. 21, pp. 76–85. McKay divides the coalfield from Mount Rochfort plateau to Mokihinui into three sections, which are in large part determined by faults trending in northerly and southerly directions (Lower Buller and Mount William faults). There is a map facing p. 80, and coal-analyses are given on p. 85.

1892. Binns, G. J.: "Mining in New Zealand." Trans. Fed. Inst. Min. Eng., 1892, pp. 8–12, 49, 52, 54, and 71. (Not seen.)

1893. McKay, Alex.: "Geological Explorations in the Northern Part of Westland." C.–3, pp. 132–86. There is little direct reference to the geology of the area included in the Buller-Mokihinui Subdivision, but on pp. 156–57 a few quotations from Hector (Rep. G.S. during 1866–67, No. 4, 1868) have bearing on the origin of the alluvial gold of the Buller district.

1894. McKay, Alex.: "On the Geology of the Northern Part of Westland and the Gold-bearing Drifts between the Teremakau and Mikonui Rivers." Rep. G.S. during 1892–93, No. 22, pp. 11–50. McKay briefly quotes previous reports by Hector discussing the origin of the auriferous drifts of the West Coast. He notes on p. 30 the general steep dip of the blue Miocene clays (Blue Bottom) near the ranges and near the outcrops of older rocks.

1895. McKay, Alex.: "Geology of the South-west Part of Nelson and the Northern Part of the Westland District." Mines Report, C.–13. There is abundant useful information both as to the general and the economic geology of the Westport area in this valuable report.

1896. McKay, Alex., and Gordon, H. A.: "Mining Reserves, Nelson and Westland." Mines Reports, C.–9. In this paper are important statements as to the geological history, stratigraphical sequence, and economic geology of the district dealt with by the present bulletin.

1896. Gordon, H. A.: "The Hysteromorphous Auriferous Deposits of the Tertiary and Cretaceous Periods in New Zealand." Trans. Amer. Inst. Min. Eng., vol. xxv, pp. 292–301. Pages 297 and 298 contain references to auriferous deposits near Cape Foulwind and the Buller Gorge.

1898. Don, J. R.: "The Genesis of certain Auriferous Lodes." Trans. Amer. Inst. Min. Eng., vol. xxvii, pp. 564–668. In the course of his elaborate investigation on the gold-silver content of various rocks, Dr. Don assayed two samples of mica from Cape Foulwind and found that neither contained either gold or silver.

1898. McKay, Alex.: "Notes on the Auriferous Ironsands of New Zealand." *Mines Record*, vol. i, pp. 395–96, 446–50. The ironsands of the Westport district are discussed in moderate detail.

1899. Evans, W. P.: "Analyses (Technical) of New Zealand Coals." Trans., vol. xxxi, pp. 564–65. Several coals from the Westport district are discussed.

1899. Evans, W. P.: "On the Apparent Occlusion of Sulphuretted Hydrogen in a Bituminous Coal." Trans., vol. xxxi, pp. 566–67. The sample of coal tested was from the "Hannah Hector" outcrop of the Westport-Cardiff Coal-mine (later part of the Seddonville State Mine).

1899. "The Mokihinui Coal-mine (Papers relating to)." C.–8.

1899. Park, James: "Notes on the Coalfields of New Zealand." Coll. Guardian, vol. lxxviii, pp. 1214, 1215. (Not seen.)

1899. McKay, Alex.: "Notes on the Auriferous Ironsands of New Zealand." Mines Reports, C.-9, pp. 15-16. This paper contains much the same information regarding the Westport district as McKay's former paper in *Mines Record*, vol. i, 1897-8. (See also *Mines Record*, vol. iv. 1900-1, p. 321; "The New Zealand Mining Handbook," 1906, pp. 333-34; and *Colliery Guardian*, vol. lxxv, 1898, p. 1041.)

1900. Hutton, F. W.: "The Geological History of New Zealand." Trans., vol. xxxii, pp. 159-83. Amongst other details of geological history, Hutton, assuming the Maitai rocks to be of Carboniferous age, considers most of the granites along the axis of the Southern Alps to have been intruded during a period of folding in the Permian. Some of the granites, however, may be Jurassic. Hutton's Waipara System includes the Westport bituminous coals.

1900. Hector, James: "Iron Ores and Sands of New Zealand." (Reprint from "Handbook of New Zealand," 1886.) *Mines Record*, vol. iii, p. 473.

1900. Park, James: "Notes on the Coalfields of New Zealand." Proc. Inst. Mining and Metall., vol. viii, p. 146 (see also *Mines Record*, vol. iii, p. 349). In this paper Park places the bituminous coals in the Eocene. A similar view is taken by the writers of this bulletin. See Chapters III and V.

1900. "Fire at Cardiff Coal-mine (Papers and Correspondence relative to)." C.-8.

1900. "Coal Committee: Report and Evidence." I.-7. This Committee was set up to report on the prices for coal. There is some information in the report regarding the physical characters and best means of handling the Westport coal.

1901. "Coal-mines of New Zealand (Report of Royal Commission appointed to inquire and report on the Working of), together with Minutes of Evidence." The report embodies full historical details concerning the mines worked by the Westport Coal, the Westport-Cardiff, and the Mokihinui Coal companies. Several important recommendations were made by the Commissioners.

1901. "Proposed State Colliery: Reports by Messrs. H. A. Gordon, A. McKay, John Hayes, and A. Jamieson on the Coal Areas in the Westport-Cardiff Colliery." C.-9. Several recommendations with regard to trial bores and other matters were made by the authors of this report.

1901. McKay, Alex.: "Report on Prospect of Coal at Waimangaroa Railway-station, Westport." C.-10, p. 6. Some useful information about the disposition and thickness of the coal-bearing beds near Waimangaroa has been presented by McKay in this paper.

1903. Hamilton, A.: "List of Papers on the Geology of New Zealand." Trans., vol. xxxv, pp. 489-546.

1903. McKay, Alex.: "Gold-deposits of New Zealand." In this book, which consists mainly of reprints from *Mines Record*, vols. v and vi, the author on pp. 20-27 discusses the gold occurrences near Westport, and on p. 27 mentions the occurrence of galena in a reef at Cascade Creek.

1903. "State Coal-mines (Report on the Working of)." Mines Report, C.-3B. This is a general report on the State coal-mines of the west coast of the South Island by the Manager, Mr. A. B. Lindop. Similar reports, with maps, by Messrs. James Bishop, James Fletcher, and I. A. James, appear in the Mines Reports of succeeding years.

1904. Park, James: "On the Age and Relations of the New Zealand Coalfields." Trans., vol. xxxvi, pp. 405–18. After criticizing the Cretaceo-Tertiary classifications of the Geological Survey, and reviewing Captain Hutton's division of the coal-measures into four series, Park divides the coalfields into two divisions —viz., the Oamaru (Miocene) and the Waipara (Cretaceous). The brown coals fall mainly in the Oamaru Series and the bituminous in the Waipara.

1905. "Goldfields and Mines Committee: Report on Petition regarding Management of the State Mine at Seddonville, together with Minutes of Evidence, Reports, Papers, and Appendix." I.–4B. In the evidence there is criticism of the colliery, and in the appendix are particulars regarding trials of Seddonville coal in various steamers.

1905. Marshall, P.: "Geography of New Zealand." The author makes general references to physical features and economic resources of the area comprised in the Buller-Mokihinui Subdivision.

1905. Park, James: "Ores and Useful Minerals considered economically." *Mines Record*, vol. viii, pp. 189–200, 241–45, and 288–91. On p. 193 Park states that the bituminous coals of New Zealand are of Upper Cretaceous Age. This work appeared in pamphlet form in 1905, and was included also in "A Text-book of Mining Geology" (see below).

1906. Park, James: "A Text-book of Mining Geology for the Use of Mining Students and Miners." This book contains Park's previous paper, "Ores and Useful Minerals considered economically" (1905), and has a few further references to Westport geology.

1906. Gordon, H. A.: "Mining and Engineering and Miners' Guide" (2nd edition). On p. 13 is a reference to the occurrence of osmium-iridium near Mokihinui.

1906. Loughnan, R. A.: "First Gold Discoveries in New Zealand." *Mines Record*, vol. ix, pp. 497–503, and vol. x, pp. 1–9, 43–52, and 87–102. The material of this essay was reprinted in pamphlet form later in the same year.

1906. Ross, Kenneth: "Some Experiments on the West Coast" (published in *Buller Miner*). See *Mines Record*, vol. x, pp. 12–13.

1906. Bell, J. M.: "The Salient Features of the Economic Geology of New Zealand." *Economic Geology*, vol. i, No. 8. (See extract in *Mines Record*, vol. xi, 1907–8, p. 335.) Contains references to the Westport coal and to the general geology of New Zealand.

1906. Galvin, P., and others: "The New Zealand Mining Handbook." This publication, besides numerous reprints of papers by various writers, and various statistics, contain several articles not previously published that have reference to the Westport District. These are—

Bell, J. M.: "A Sketch of the Economic Geology of New Zealand" (pp. 1–6).

Gordon, H. A.: "The Rise and Progress of the Gold-mining Industry" (pp. 7–38).

Hayes, John: "Coal-mining in New Zealand" (pp. 383–96).

Gordon, H. A.: "Seddonville State Mine" (pp. 425–37).

McKay, Alex.: "Further Notes on the Iron-ores of New Zealand" (pp. 471–72).

1906. Sollas, W. J., and McKay, Alex.: "The Rocks of Cape Colville Peninsula," vol. ii. This, on p. 159, contains a description of granite from Cape Foulwind.

1907. Townson, W.: "On the Vegetation of the Westport District." Trans., vol. xxxix, pp. 380–439. On pp. 383–86 the author records the geology of the district, chiefly by means of quotation from McKay's paper, "Report on the Geology of the South-west Part of Nelson and the Northern Part of Westland" (C.–13, 1895).

1907. Bell, J. M.: "The Mineral Wealth of New Zealand." Journ. Roy. Colonial Inst., vol. xxxix, pp. 38–56, and *Mines Record*, vol. xi, 1907–8, p. 240 (extract).

1907. Maclaurin, J. S.: "Report on Analyses of New Zealand Coals made at New Zealand International Exhibition, Christchurch, 1906–7." Proximate analyses of eight samples of Westport coal are given on p. 6.

1908. Maclaren, J. Malcolm: "Gold, its Geological Occurrence and Geographical Distribution." On p. 54 the author states that he considers that gold-deposition on the West Coast may be genetically connected with the granites intruded during the Middle Mesozoic uplift of the Southern Alps. Page 91 has a brief reference to the auriferous beach-sands of New Zealand.

1908. Bell, J. M.: "New Zealand as a Mining Country." *Australian Mining Standard*, No. 28, and *Mines Record*, vol. xii, 1908–9, p. 289. In this is a brief reference to the Westport coal-deposits.

1909. Reed, F.: "Coal-mining Methods in New Zealand." *Mines Record*, vol. xii, p. 226.

1909. Park, James: "Outline of New Zealand Geology." *Mines Record*, vol. xii, pp. 294–97, 337–41, 387–90, and 443–40. This sketch of New Zealand geology was later expanded into book form in "The Geology of New Zealand," 1910

1909. Bell, J. M.: "Mining in New Zealand." *Australian Mining Standard*, 1909.

1909. Bell, J. M.: "The Economic Geology of New Zealand." Proc. Aust. Inst. Min. Eng., vol. xiii, 1909, p. 66.

1909. Park, James: "History of Mining in New Zealand." The *Mining Journal*, London, 75th Anniversary Number, Aug., 1909.

1910. Park, James: "The Geology of New Zealand." In this book the author makes numerous references to points concerning the geology of the Buller - Mokihinui Subdivision; chapters viii and xiii, dealing with the coal-measures, are particularly important. The bituminous coals are placed in the Waimangaroa Series of Eocene age, and the brown coals in the Oamaru Series of Miocene age. The bibliography given on pages 409–64 is very useful.

1911. Morgan, P. G.: "The Geology of the Greymouth Subdivision, North Westland." New Zealand Geological Survey Bulletin No. 13 (New Series). This deals with an area similar in many ways to the Buller-Mokihinui Subdivision, and contains brief references to its geology.

1911. Morgan, P. G.: "Field-work in the Buller-Mokihinui Subdivision." Fifth Annual Rep. (N.S.) of the N.Z.G.S., pp. 3–9.

1911. Marshall, P., Speight, R., and Cotton, C. A.: "Younger Rock Series of New Zealand." Trans. vol. xliii, pp. 378–407. On pp. 401–2, this paper, important by reason of its bearing upon the question of the ages of the New Zealand coal-measures, contains a summary of the views held by Professor Park as to these ages.

1911. Marshall, P.: "New Zealand and Adjacent Islands." Handbuch der Regionalen Geologie, 5 Heft, Band vii, Abteilung 1. This publication has many statements relative to the geology of the Westport district.

1912. Marshall, P.: "Geology of New Zealand." On page 144 there is mention of gold beaches and gravels near Westport, and, on p. 159, of the coal of the district. Marshall (p. 190) places Hector's "Buller Series," which originally included the bituminous coal-seams of the Westport district, in the Oamaru Series. He does not consider that there is any evidence of the coal having been deeply covered.

1912. "Royal Commission on Mines (Report of)." C.-4, Sess. I. On pp. 33–35 is a section on "The Profitable Utilization of the Soft Bituminous and Lignite Coals of the Westport District of New Zealand," and on pp. 152–67 is the evidence taken with regard to briquette-manufacture.

1912. Morgan, P. G.: "Field-work in the Buller-Mokihinui Subdivision." Sixth Annual Rep. (N.S.) of the N.Z.G.S., pp. 3–4.

1913. Morgan, P. G.: "Field-work in the Buller-Mokihinui Subdivision"; "The Coal Possibilities of the Westport Flats"; "Cement-materials near Cape Foulwind." Seventh Annual Rep. (N.S.) of the N.Z.G.S., pp. 117–19, 124–28.

1913. Morgan, P. G.: "Coal Resources of New Zealand." Proc. Aust. Inst. of Min. Eng. (New Series) No. 9, pp. 1–27. Contains brief descriptions of the Buller-Mokihinui and the Charleston-Brighton coalfields, with estimates of quantity of coal available. (See also "Coal Resources of the World," Toronto, 1913, which contains (pp. 71–85) a similar article.)

1914. Thomson, James Allan: "Materials for the Palæontology of New Zealand." Palæontological Bulletin No. 1, N.Z.G.S.

1914. Bartrum, J. A.: "The Geological History of the Westport-Charleston High-level Terraces." Trans., vol. xlvi, pp. 255–62.

1914. Bartrum, J. A.: "Some Intrusive Igneous Rocks from the Westport District." Trans., vol. xlvi, pp. 262–69.

1914. Morgan, P. G.: "Unconformities in the Stratified Rocks of the West Coast of the South Island." Trans., vol. xlvi, pp. 270–78.

Brief references too numerous to be included in the above list are also to be found in the Annual Reports of the Colonial Museum and Laboratory, which later appear for some years as the Reports of the Colonial and more recently as those of the Dominion Laboratory. In these useful reports the results of most of the analyses and assays executed at the Laboratory are yearly published; in the earlier reports of the Colonial Museum and Laboratory geological data were also included.

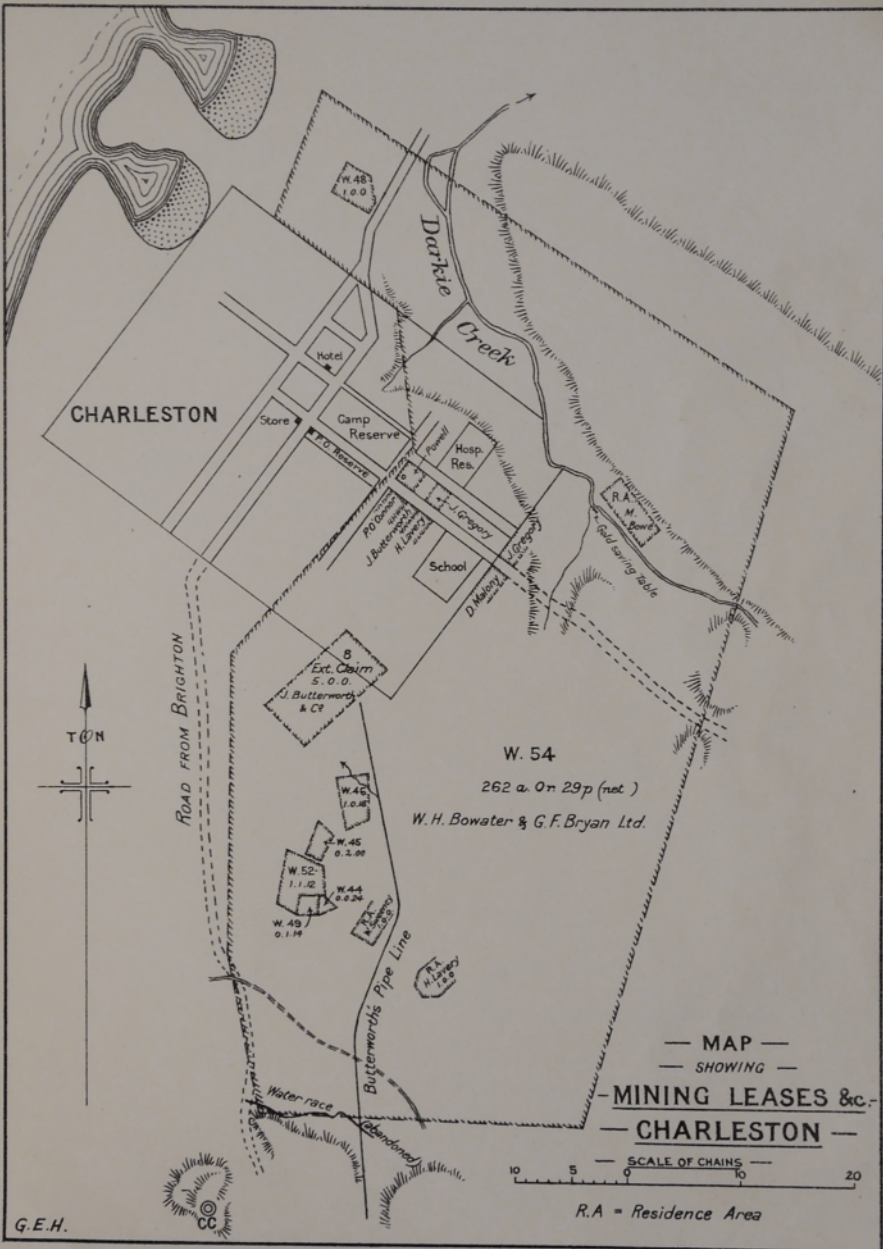
The *New Zealand Mines Record*, published monthly from August, 1897, to May, 1909, and the Reports of the New Zealand Mines Department ("Papers and Reports relating to Minerals and Mining"), which have appeared annually since 1887, contain a great quantity of useful information, supplied chiefly by the reports of the Wardens and Inspectors of Mines.

There are also numerous more or less passing references to New Zealand geology and mining in many mining journals and other publication published beyond New Zealand, but it has been found impracticable to refer to more than the most important of these.

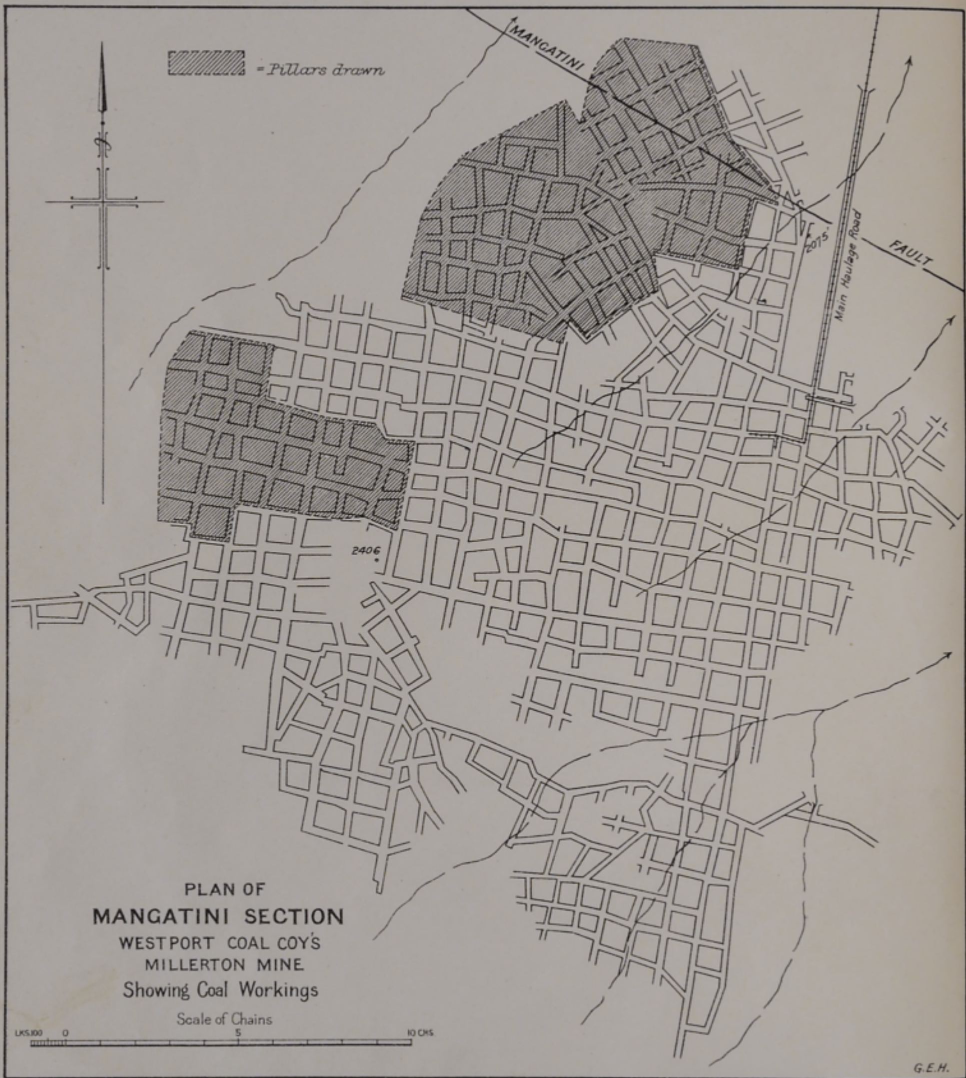
In the early copies of the *Nelson Examiner* references to the early explorations of the province are to be found, but access to such papers was not obtainable by the writers of this bulletin.

Lastly, the reports of Inspectors of Mines and Goldfields Wardens previous to 1887, and various other similar reports and papers appearing, like them, in parliamentary papers, are a source of useful knowledge with regard to the history of mining. Most of those having any noteworthy reference to the Buller-Mokihinui Subdivision will be found in the following list: 1872, G.–4; 1873, H.–7; 1874, H.–9; 1875, H.–3, H.–27; 1876, H.–3; 1877, H.–1; 1878, H.–4; 1879, Sess. 1, H.–16; 1879, Sess. II, H.–11, I.–3A; 1880, H.–18, H.–26; 1881, H.–14, H.–17; 1882, H.–13, H.–19; 1883, H.–5, H.–11; 1884, Sess. I, C.–2, C.–5, H.–9; 1885, C.–2, C.–4, C.–6; 1886, C.–2, C.–4, C.–4A, C.–4C.

To the above list may be added: 1873, E.–2A (pp. 5–11), and a few other parliamentary papers.



— MAP —
— SHOWING —
- MINING LEASES &c. -
— CHARLESTON —
— SCALE OF CHAINS —
10 5 0 10 20
R.A = Residence Area
CHARLESTON
Darkie Creek
Hotel
Store
Camp Reserve
P.O. Reserve
Powell
Hosp. Res.
J. Gregory
P. O'Connor
J. Butterworth
H. Lavery
School
D. Malony
R.A. M. Bowe
Gold saving Table
W. 48 1.0.0
8 Ext. Claim 5.0.0. J. Butterworth & Co.
W. 54
262 a. 0 r. 29 p (net)
W. H. Bowater & G. F. Bryan Ltd.
W. 46 1.0.18
W. 45 0.2.00
W. 52 1.1.12
W. 44 0.0.24
W. 49 0.1.14
R.A. H. Lavery 1.0.0
ROAD FROM BRIGHTON
Butterworth's Pipe Line
Water race (abandoned)
T N
CC
G.E.H.



= Pillars drawn
MANGATINI
FAULT
Main Haulage Road
2075'
2406
PLAN OF
MANGATINI SECTION
WESTPORT COAL COY'S
MILLERTON MINE
Showing Coal Workings
Scale of Chains
0
5
10 CHS
G.E.H.

CHAPTER II.

THE MINING INDUSTRY.

Introduction.

Half a century ago the alluvial gold of the Westport district was just beginning to attract attention: then quickly came rush after rush, and almost at a bound alluvial mining reached its zenith. Many small fortunes were rapidly made, and in some cases as rapidly lost. In a few years gold-mining began to decline, and in spite of the skill and the industry of the miner the decline has continued almost uninterruptedly to the present time, so that to-day the gold-production as compared with that of forty to fifty years ago is relatively unimportant. As gold-mining fell away, however, the more prosaic but more solid industry of coal-mining grew and expanded, until now it has become the mainstay of the Westport district.

The various mining operations of the subdivision resolve themselves into three classes —namely, alluvial gold-mining, lode mining, and coal-mining. In addition, the extensive quarrying-works conducted by the Westport Harbour Board at Cape Foulwind may be regarded as falling into the category of "mining."

(1.) Alluvial Gold-mining.

General and Historical Account.

The credit for the discovery of gold in the western part of the South Island probably belongs to a member of John Rochfort's survey party, who, on the 8th November, 1859, accidentally found a small nugget during the progress of his daily work on the bank of the Buller River at or near the spot now known as "Old Diggings." A party of miners from Nelson is also said to have found gold in the Buller River before 1860. Many diggers were soon at work on the banks of the Buller and other streams, and on the sea-beaches, but there is little recorded concerning the progress of gold-discovery in these early days. Burnett, however, in 1862, states that the Waimangaroa was then being worked for gold.

In 1865 highly important discoveries of ancient beach leads rich in gold were made at Charleston and Brighton, and during 1867 similar leads were found at Addison's and probably also at Bradshaw's, which, according to the early Warden's reports, was then considered as part of Addison's Flat. In the same year rich auriferous gravels were also found north of the Buller at Caledonian, German, Giles, and Rochfort terraces, and the discovery of old beach leads at the mouth of the Mokihinui soon followed.

The abundance of gold caused great excitement, and presently twenty thousand miners, it is said, were at work between Brighton and Mokihinui. In some cases, however, the leads were shallow and were quickly exhausted, so that the number of diggers rapidly decreased after the first few years. In 1887 not more than five hundred men were at work on the alluvial deposits, and in 1912 the total number of alluvial miners in the whole district, including Karamea, was only seventy-one.*

In the earlier days of alluvial mining gold was won chiefly by various methods of ground-sluicing, driving-out, and black-sanding; but about 1887, so far as can be gathered from the available reports, cement-crushing, which had begun as early as 1872, was being extensively prosecuted at Charleston, Addison's, and Bradshaw's, and the important innovation of hydraulic sluicing was being tried at Fairdown. The introduction of dredging to the district dates from 1888 or thereabouts, when McQueen and Co.'s dredge was built near the beach a few miles south of the Ngakawau River.† A year or two later several dredges were at work in the Buller River and elsewhere, but on the whole were not commercially successful, partly perhaps through the lack of gold in the wash, but more largely through faults in construction and unexpected difficulties and misfortune. In 1900 a dredging "boom" set in, and a considerable number of new dredges was built. In many cases, however, the prospects on which the new concerns had been floated were selected in the interests of the seller from favourable spots, and in several instances were the results of "salting."‡ Through these causes, added to others, such as failure to profit by previous experience, the dredging "boom" ended in disastrous failure. A few of the companies were reconstructed, mostly on the basis of private ownership, and these struggled on for a few years, with occasional gleams of success.

At the present time dredging has ceased, and alluvial mining is confined to a little desultory cement-crushing, to black-sanding, and to the sluicing operations of a few parties of miners.

Hydraulic and Ground Sluicing.

Even at the present time, when the richest and most accessible ground has been worked out, a moderate amount of gold is still being won profitably by sluicing. In the Westport district the chief centres of activity are Charleston, Addison's Flat, Bradshaw's, and Fairdown. Among the claims at work are Powell's, near Charleston; McCann's, McKnight's, Carmody's, and the Shamrock (Westland Gold-mining Syndicate), at Addison's; Dennehy's at Bull's; and the Carthage Company's claim, near Fairdown. Various disadvantages, many of which are common to all alluvial fields, reduce profits, and prevent old claims from being worked on a larger scale or new ones from being started. The chief of these are—

(1.) Long water-races and expensive pipe-lines are in most cases required to bring the necessary water to the claims.

(2.) The chief gold-content of the gravels being worked is usually in leads more or less deeply covered by barren, or nearly barren, gravels, which have to be sluiced away in order to enable the gold-bearing wash to be reached.

(3.) There is seldom adequate fall for tailings, hence elevating methods become necessary.

* Mines Report, C.-2, 1912, p. xvii.
† Mines Report, C.-2, 1889, p. 63.
‡ See Mines Report, C.-3, 1902, p. 100.

(4.) The bulk of the gold is in minute particles, and there is consequently a difficulty in saving it, this difficulty being increased when the gold is "rusty."

(5.) On account of the gold occurring in runs or leads which are not continuous but lenticular, the distribution of payable wash is patchy and uncertain.

(6.) In some places tightly cemented black-sand beds have to be broken by explosives before they can be sluiced.

In few claims have the large fluvio-glacial boulders so common in the auriferous gravels of Westland to be removed. The Carthage Company, however, has experienced considerable difficulty with buried timber. As a general rule, the material is a convenient size for sluicing (as might be expected with beach deposits), and except in the cemented black-sand layers, does not appear to be particularly tight.

In the earlier workings the ground was shallow, and, as previously mentioned, usually consisted of beach gravels and sands, with their auriferous content chiefly in black-sand layers. In a few claims the gold seems to have been further concentrated by stream-action. At the present day the deeper leads alone remain to be worked.

The bottom on which the gold-bearing material rests varies widely. Near Charleston shallow drift commonly lies on wave-cut benches of Tertiary coal-measures or of underlying gneiss, but "false" gravel and sand "bottoms," here as elsewhere, are also common. At Addison's Flat blue Miocene claystone formed the bedrock of many of the claims now abandoned, and hence arose the miners' term of "Blue Bottom." The black-sand lead between Fairdown and the sea, worked by the Carthage Company, rests on a "false bottom" of marine material.

A brief account of the sluicing methods may be of interest. Ground-sluicing, the prevailing method of the pioneer miners, is now generally superseded by the hydraulic methods suited to the deeper ground. Where, as is commonly the case, the material has to be elevated, one of two methods of effecting this is adopted. The first, the "blow-up" method, requires considerable head and volume of water, and consists in sluicing the gravels into a short race leading to a small hopper, from which a rising pipe connects with the gold-saving plant. A strong jet of water, entering the rising or "elevating" pipe under high pressure, sucks the material in the hopper into the pipe, and by its impetus carries this to the top, where the coarse gravel, after passing over iron gratings, is washed to the tailing-dump, whilst the fine material is distributed over the gold-saving tables. In the second or water-balance method of elevating, the drift is carried by ground or hydraulic sluicing into a somewhat long hopper; this has a grating bottom through which the fine material and water escape to a tail-race tunnel, whilst the coarse stuff is discharged periodically from the end of the hopper into a waiting truck, and is drawn upwards on an inclined tramway to a tipping-platform by a downward-running water-filled truck or tank. This latter is again raised to the tipping-platform by partly filling the discharged stone truck with water. At Addison's Flat the great disadvantage of the alluvial claims is that lack of fall necessitates the driving of costly tail-race tunnels, some of which are over a mile in length. Through these the fine portion of the wash passes with the water to the gold-saving tables. The construction of the tables involves no points of special interest. The concentrates are collected on them by "blanketing" of various fabrics, and are then, as a rule, treated in amalgamating-barrels in order to recover the gold.

Driving-out.

In the early years of the goldfields the deeper ground, particularly at Addison's Flat, was extensively worked by means of driving-out. This method of mining, however, being applicable only to comparatively rich ground, is now almost obsolete in the Westport district, with the exception that a little driving, more by way of prospecting than anything else, is still occasionally done on deeply covered cement leads.

Black-sanding.

Black-sanding consists in extracting the gold from the auriferous black-sand of the present sea-beaches. Originally of great richness, the beaches have been so often worked that they now yield but a scanty and uncertain return to the one or two dozen men who spend occasional days at black-sanding. Beach-sands have been worked for some miles both east and west of the mouth of the Buller, and more especially at Rahui ("The Beach") near Charleston, where an interesting method of black-sand treatment is in vogue (see Plates III and IV). The claims are pegged as long narrow strips at right angles to the coast-line. To these water is brought by a number of wooden flumes, from which it is distributed by flexible pipes to the washing-appliances, these being mounted on stout hand-barrows. The gold-bearing sand and gravel are shovelled into hoppers, which retain the coarser material on gratings, whilst the sand, along with the gold, passes through the gratings to narrow tables covered by sacking, blanketing, matting, or plush. The gold is recovered from the table concentrates by amalgamation. In the neighbourhood of Westport the gold-saving appliances generally used are small amalgamated copper plates set on a portable wooden frame, similar to those used in North Westland.

Dredging.

Reference has already been made to McQueen and Co.'s dredge, built south of the Ngakawau River in 1888. The gold-saving appliances were found ineffective, and gold, it may be suspected, was not overplentiful, so that work soon ceased.* The McQueen Company was followed by the New Era Company, which erected a dredge near the beach about fifteen miles north of Westport, and in 1891 began active operations. The returns, however, were poor, and work was soon stopped.† Numerous dredging claims were pegged out in 1888 on or near the coast of the subdivision, but only those mentioned above are known to have been in actual operation during the next few years. During the dredging "boom" of 1900 many claims were taken up in the coastal plain district. Several of these, for example the Island Creek,‡ and Wareatea, which were floated on the strength of excellent prospects, failed to recover any appreciable amount of gold when dredging operations began. The Fairdown Gold-dredging Company had partly built a dredge when, owing to rumours of "salting" in a neighbouring claim, the claim was reprospected, with most unsatisfactory results.§ The Wareatea dredge was bought by the Waimangaroa River Gold-dredging Company, and re-erected near Waimangaroa during 1902. Owing, it is stated, to large boulders, the dredge was unsuccessful, and work was entirely stopped in 1903. During this year the New Fairdown Gold-dredging Company is recorded as having obtained 177 oz. of gold, worth £703; but no other particulars are available. In all, five or six dredges are known to have been built between Westport and Ngakawau, but none is known to have obtained any large quantity of gold, or to have paid working-expenses for even a short period.

The Buller River has been dredged from near the Blackwater River junction to a point not far below Lyell. Only the first two or three miles and the last mile of this

* Mines Report, C.-3, 1890, pp. 85-86.
† Mines Report, C.-3A, 1892, p. 18.
‡ This dredge was located near Waimangaroa, and not at Island Creek south of the Buller.
§ Mines Report, C.-3, 1902, p. 100.

BLACKSANDING AT RAHUI, NEAR CHARLESTON.

[*To face page 26.*

part of the river are in the subdivision as mapped, but it will be convenient to give a sketch of the dredging industry on the whole of the river below Lyell. The first dredge on the Buller River was that built by the Whitecliffs Dredging Company, which began work at the "Old Diggings" in 1891.* Very poor returns appear to have been obtained. Soon after the company failed, owing to its dredge being wrecked during a fresh in the river. The dredge was bought by a working party, raised, and successfully reworked as the "Cocksparrow" dredge. In 1893 it was shifted up the river to the neighbourhood of Three-channel Flat,† where some profitable returns were obtained. For several years, during which the "Cocksparrow" was moved up and down the Buller from Feddersen's Farm, two or three miles from Lyell, to a short distance below Inangahua Junction, and changed ownership and title on several occasions, becoming successively the Exchange and the Consolidated and finally‡ the Old Diggings, there was little alteration in the dredging industry. In 1900, however, the Mokoia was at work on the Buller near Three-channel Flat, and the Rocklands Beach, Buller Junction, Premier, and Welcome dredges were in course of construction. In 1901 the Eldorado and Feddersen (afterwards the New Feddersen) gold-dredging companies were building dredges. The ancient Cocksparrow was brought down the river to a point above Berlin's, and there was intermittently worked by the Old Diggings Gold-dredging Company.

All these dredges had chequered careers. The Mokoia, which was on the whole the most successful, after obtaining some gold, was sold about 1906 to Messrs. De Fillippi and others, who got some good returns. They then sold the dredge to a company or syndicate known as the New Mokoia, which was not successful, and in 1911 went into liquidation. The Feddersen Gold-dredging Company's dredge was stranded shortly after it began operations. The company then sold out and went into liquidation about the end of 1903, the Welcome and Premier companies (Three-channel Flat) following suit in 1904, and the Rocklands Beach in 1905. The various dredges were nearly all subsequently worked by private companies or syndicates, and several changed hands more than once. In 1907 there were only three dredges working on the river between Lyell and Westport, and in 1911 all operations ceased.

The only dredging returns available are those obtained by the publicly registered companies, which on the whole were far from payable, though some dividends were declared. The private syndicates composed of working shareholders, who had bought second-hand dredges for little or nothing, did better, but probably none made any great profit. The chief reason for this comparative failure was not so much the want of gold as the severe floods in the river, which time after time caused the dredges to sink at their moorings or to break away. Another factor promoting failure was the inefficient design of several of the dredges.

The following particulars have been gathered from the Mines Reports issued during the past twenty years, and, though incomplete, will give a fairly accurate idea of the vicissitudes of dredging on the Buller River. The Cocksparrow Gold-dredging Company during the years 1894 to 1896 obtained 1,981 oz. of gold, worth £7,474, and paid £525 in dividends. The Exchange Gold-dredging Company, which subsequently owned the dredge for two or three years, seems to have been a private syndicate, with headquarters at Christchurch, and its returns do not appear in the Mines Reports. The Consolidated Dredging Company, with the same dredge from 1899 to 1901, obtained 533 oz. of gold, worth £2,084, but paid no dividends. The Mokoia Gold-dredging Company obtained 5,271 oz. of gold, worth £20,081, between 1901 and 1905: the dividends paid

* Mines Report, C.-3A, 1892, p. 18.

† Mines Report, C.-3A, 1894, p. 27.

‡ Mines Report, C.-3B, 1898, p. 4, casually mentions the "Excelsior dredge, Three-channel Flat." This may be the "Cocksparrow."

amounted to £1,925. The Feddersen Gold-dredging Company in 1903 obtained 477 oz., worth £1,825; the New Feddersen Gold-dredging Company between 1904 and 1906 obtained 2,092 oz., worth £8,202, and paid £1,272 in dividends. The Premier Gold-dredging Company between 1901 and 1903 obtained 1,496 oz., valued at £5,882, and paid £262 in dividends. The Buller Junction Gold-dredging Company between 1901 and 1903 obtained 3,809 oz., worth £14,865, and paid £3,488 in dividends. A further 439½ oz. (worth, say, £1,714) was won in 1904.* The Rocklands Beach Gold-dredging Company between 1902 and 1904 obtained 2,313 oz., worth £9,080, but paid no dividend.

In all, the six dredges and eight companies whose returns are known obtained from the Buller River 18,411 oz. of gold, worth approximately £71,207, and paid only £7,472 in dividends. The profits made by private syndicates probably did not cover the sums expended by them in buying and repairing dredges. Since eight dredges were built, and since all at one time or another were worked at a loss, it is evident that gold-dredging on the Buller River was an unprofitable industry.

Cement Mining.

Owing to peroxidation of the iron-content having caused the auriferous black-sands of the old beach leads in many places to become firmly cemented, they have to be crushed in order to allow extraction of the gold. In past years the usual method of doing this was to crush the cement in a stamper battery which discharged on tables covered with blanketing or similar material. The concentrates from these were finally amalgamated in order to recover the gold. In some cases copper plates were used, as well as blanket tables. Considerable difficulty was experienced in saving the gold, partly on account of its fine state of division, which caused flotation losses, and partly by reason of a thin coating of iron oxide on the gold grains, which prevented amalgamation.† Various methods of remedying these troubles were tried, among these being the use of sodium amalgam to promote amalgamation, and cyanidation as a substitute for amalgamation. The latter method, however, after being tested at Bradshaw's,‡ was deemed unsuccessful.

Had it not been for the very considerable gold-losses, the cement claims would have been profitable concerns, for, according to returns in the Mines Report of 1893, the cement crushed at Addison's Flat averaged 10 dwt. per ton, whilst the battery costs were extremely low. There seems to be no reason why, with the aid of modern knowledge, such or even much poorer material should not be profitably treated.

At the present time the only cement-crushing in the Westport district is the little occasionally done when other work is slack, by a few of the settlers in the Charleston district.

"Fly-catching."

In past years some of the fine gold, and more especially the float gold that escaped from the cement batteries and the sluicing claims of the Bradshaw's-Addison's-Charleston district, was recovered by various devices, most of which came under the designation of "fly-catching." The principal of these devices consisted of tables covered with coconut-matting, blanketing, canvas, or similar material, which were placed in the tail-races and stream-channels, and over which the tailings and water ran in a very thin stream.§ In this way very profitable returns were frequently obtained.

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* Mines Report, C.-3, 1905, p. 100 (table in Warden's Report).

† The question of "rusty" gold is further discussed in Chapter VI.

‡ Mines Report, C.-3, 1910, p. 43, and C.-3, 1911, p. 33.

§ The only noteworthy references to "fly-catching" observed in the Mines Reports will be found in C.-5, 1888, p. 36, and C.-2, 1889, p. 61. McKay's reports make casual mention.

(2.) Lode Mining.

The first record of the discoveries of metalliferous lodes in the Buller-Mokihinui Subdivision in the literature available to the writers is given by parliamentary paper H.-7, 1873, wherein the Warden for the Westport district mentions the "old reefing claim" found in Cascade Creek, and also the discovery of a reef up the Mokihinui River in the locality now sometimes called Seatonville.* In spite of incredible difficulties in the matter of transport, gold-seekers soon erected machinery on the Mokihinui River claims. The Halcyon was the first battery to do any crushing, but results were apparently unsatisfactory, and no further record of the district is found until 1882, when, in the Warden's report, it is stated that good gold had been discovered near the old Halcyon Claim. In consequence the South Pacific, Red Queen, and Mokihinui companies were actively developing their claims, whilst the Guiding Star, Morning Star, and Golden Crown companies were prospecting. Meanwhile the Christmas Eve Company was prospecting in Cascade Creek, and the Try Again and Great Republic companies were at work in Stony Creek, near Waimangaroa, where also gold-bearing lodes had recently been discovered.

The Red Queen Company was successful in finding some small and lenticular but rich veins, from which 1,560 tons of quartz, yielding 29 dwt. of gold per ton, was extracted,† and £2,400 paid in dividends. During 1885 a lode 1 ft. to 2 ft. thick, very flat, and encased in very hard country, was worked.‡ In 1886 the lode was reported as 6 in. to 18 in. wide, with well-defined walls. In this year the Southern Light Company and the Mokihinui Company were also at work. No work of any consequence was done at Mokihinui Reefs for some years, but in 1890 and 1891 the Red Queen and South Pacific (or South Pacific Extended) claims were again being worked. The Nile Gold-mining Company, which since 1888 or earlier had been prospecting an area in Rough-and-Tumble Creek, and had built a small battery, was reported in 1890 as defunct. In 1895 the hardy Red Queen Company and the Swanston Company were again prospecting at Mokihinui Reefs. In 1897 the Lady Agnes Claim was also being prospected. After being practically abandoned for several years the Mokihinui Reefs district was again given a trial in 1901 and 1902, in which latter year the Red Queen was working a 6 in. to 9 in. leader. The Lady Agnes was worked in 1903, but results were unsatisfactory. The Red Queen, however, obtained some gold year by year till 1910. Desultory prospecting continued, and during 1911 and 1912 a massive quartz outcrop which had been previously neglected was prospected with apparently favourable results. Towards the end of 1912 the Red Queen property became merged in Swastika Gold-mines, Limited, which has since continued to develop the quartz blow mentioned above, and several small veins in the same locality, but at a higher level.

In 1874 a quartz lode was discovered in New Creek,§ a small stream flowing into the Buller about two miles below the ancient mining township of Lyell. Among the mines prospected at that time or later were the Victory United,|| the Victor Emmanuel,|| the Tichborne, and the Sir Charles Napier. The last three claims were in the area which has lately been geologically surveyed. The Victor Emmanuel Company erected a battery, the remains of which may still be seen near the junction of Tichborne and New creeks, but the returns therefrom, if any, are not available. Of late years some development-

* Seatonville, or, as it is more commonly called, Mokihinui Reefs, is outside the subdivision, but some account of the mining companies which worked here will be given.

† Mines Report, C.-3, 1890, p. 103.

‡ C.-4c, 1886, p. 11.

§ H.-9, 1874, p. 14.

|| An account of these claims is given by T. J. Metcalf in "A Ramble through the Inangahua, Lyell, and Collingwood Reefs," circa 1882, pp. 4, 5, 10, and 11. The chief discoveries in the New Creek district were made between 1879 and 1881.

work has been done upon the Victory lode, which in places assays fairly well. The country, however, is hard, the ore-body probably small, and the locality difficult of access. Thus prospecting has again come to a standstill in the New Creek watershed.

In 1882, as previously mentioned, the Try Again and Great Republic companies were at work in Stony Creek, near Waimangaroa. The latter company erected a battery, and by 1885 had obtained 1,433 oz. of gold from 1,065 tons of quartz. Before 1890 the claim had yielded gold to the value of about £12,000,* and had paid dividends to the amount of £3,800,† but there is no record of any subsequent production, though the claim was again tested in 1895 and later years. In 1901 it was being prospected by a syndicate known as the Stony Creek Gold-mining Company. In 1895 the Britannia Gold-mining Company began a promising but on the whole not profitable career in the same locality. Gold-production began in 1900, and in 1910, when mining operations were suspended, 4,415 oz. of gold, worth, £16,645, had been obtained, and £3,342 had been paid in dividends. Since then only desultory prospecting has been done in the neighbourhood of Stony Creek. A small stamp battery with cyanide plant, &c., at a height of 1,400 ft. is still practically in working-order. It was supplied with quartz from the various mine-workings by a series of aerial and surface trams.

In 1888 the Beaconsfield Gold-mining Company began to work a lode varying from 1 ft. to 4 ft. in width on the south side of the Waimangaroa River, not far above Conn's Creek, but ceased operations about 1890. In 1897 the claim was again taken up by the Twins Gold-mining Company, which did a little development-work, and crushed some quartz in a small battery built on the north bank of the Waimangaroa, which is still standing. The results, however, were unsatisfactory.

During 1887 and 1888,‡ or thereabouts, the Denniston Quartz-mining Company prospected a small inlier of greywacke exposed about a mile to the south of Denniston. A quartz vein of no great size outcrops here, and in the workings, which consisted of a shaft 150 ft. deep with several short crosscuts, two or three leaders, carrying, it is said, payable gold, were found. The mine, however, did not reach a producing stage.

(3.) Gold-production of the Westport District.

The only records obtainable giving any statistics relating to the gold won from the Buller-Mokihinui Subdivision are the tables published in various parliamentary papers dealing with the goldfields and the mining industry. These, which from 1887 onwards will be found attached to the Mines Statements, give the quantity and value of the gold entered for exportation at Westport or as coming from the Buller County. No statistical record of gold produced prior to April, 1870, has been found, and since at that date the production of alluvial gold had already passed its zenith, the available data give an inadequate idea of the immense amount of gold that has been extracted from the auriferous deposits of the Westport district. The table following this paragraph includes most of the Lyell gold, and probably all the gold obtained by dredging on the Buller River within the Inangahua Survey District. On the other hand, some of the Buller gold was exported from Greymouth, Hokitika, and even Nelson without being credited to the producing district,§ whilst there can be no doubt that an appreciable amount of gold has been carried out of the country by Chinese diggers and others without passing through the Customs. The total production given by the table, £2,659,330, is that of Buller County rather than of the Buller-Mokihinui Subdivision. If at the end of 1886, or thereabouts, the value of gold won in the Buller district

* Mines Report, C.-3, 1898, p. 90.
† Mines Report, C.-5, 1888, p. 35.
‡ Mines Reports, C.-6, 1888, p. 17, and C.-2, 1889, p. 110.
§ "The New Zealand Mining Handbook," 1906, p. 113.

Blacksanding at Rahui. Gneissic Granite Outcrops in Background on Right.

[*To face page 30.*

amounted to £3,600,000, as estimated in 1887*, then the gold-production to the end of 1913 would be about £4,675,000. Of this four-fifths may be assigned to the Buller-Mokihinui Subdivision.

Table showing Gold exported from Westport or Buller County, 1870–1913.

Date.	Ounces.	Value.	Total from 1st April, 1870.	
			Ounces.	Value.
From Westport (Buller County after 31st March, 1889)—		£		£
1st April, 1870, to end of 1880	335,911	1,345,838	335,911	1,345,838
1st January, 1881, to 31st March, 1890 ..	90,784	363,042	426,695	1,708,880
From Buller County—				
1st April, 1890, to 31st March, 1895 ..	76,765	306,760	503,460	2,015,640
1st April, 1895, to 31st March, 1900 ..	58,197	232,728	561,657	2,248,368
1st April, 1900, to 31st December, 1905 ..	60,947	243,974	622,604	2,492,342
1st January, 1906, to 31st December, 1910	33,294	129,561	655,898	2,621,903
1st January, 1911, to 31st December, 1911	2,921	11,480	658,819	2,633,383
1st January, 1912, to 31st December, 1912	3,457	13,388	662,276	2,646,771
1st January, 1913, to 31st December, 1913	3,302	12,559	665,508	2,659,330

The gold produced by the quartz-mines of the district is included in the above table. The production of each mine, so far as ascertainable, is given in Chapter VI.

(4.) Coal-mining.

General and Historical Account.

Messrs. Charles Heaphy and Thomas Brunner, so far as can be ascertained from the available records, were the first to discover coal in the Westport district. During an exploring trip in 1846 they observed a denuded outcrop of what Heaphy describes as "capital coal" near the Waitakere River.† In 1859 Mr. John Rochfort found pieces of bituminous coal in the Waimangaroa River and reobserved lignite near the Waitakere or Nile River (Charleston).‡

Dr. Julius von Haast, in July, 1860, during the course of a geological reconnaissance of western Nelson, found a valuable seam of bituminous coal on the relatively flat upland country between Mounts Rochfort and William, close to the present township of Coalbrookdale, a name given by von Haast to the valley in which the coal outcropped.§ The discovery aroused great interest, and the Nelson Provincial Government, without loss of time, sent Mr. James Burnett to survey the coalfield. His first report, published in the *Nelson Gazette* in 1862, contains many important details in connection with the geology of the field. Mr. Burnett estimated, on what he considered a conservative basis, that 72,600,000 tons of coal could be extracted from the so-called Coalbrookdale "plateau" alone. During 1862 he also examined a 7 ft. coal-seam at the Mokihinui River; whilst in 1863 he made a more detailed inspection of this locality, the results of which were made known by a report published in the *Nelson Gazette*.

* "The Handbook of New Zealand Mines," 1887, p. 211.

† Heaphy, Charles: "Notes of an Exploration to Kawatiri and Araura [Arahura] on the West Coast of the Middle Island." *The New Zealand Journal*, vol. vii, 1847, No. 192, p. 116.

‡ J. Rochfort: "Journal of two Expeditions to the West Coast of the Middle Island of New Zealand in 1859." Jour. Roy. Geog. Soc., vol. xxxii, 1862.

§ Von Haast: "Topographical and Geological Exploration of the Western Districts of the Nelson Province, N.Z.," 1861, pp. 56, 114.

In the literature available to the writers the first record of actual coal-mining in the Westport district is a statement by Sir James Hector, made in 1867,* that some years previously a coal-mine had been opened at seven (more correctly three or four) miles from the mouth of the Mokihinui River. Probably the mine thus referred to by Hector was situated on the north bank of the Mokihinui River opposite the islands below Seddonville, slightly over three miles from the sea. At this point some development-work, including a drift on outcropping coal and a bricked shaft, was done by Messrs. E. B. Garvin and M. Batty. A small amount of coal was excavated and, the writers understand, boated or punted down the river to a small wharf near the mouth, where it was loaded on a seagoing vessel. In a much later report Hector states that "coal-seams were known and worked in an imperfect manner at Page's [Chasm] Creek within four miles of the mouth of the Mokihinui River as early as 1864 under the direction of the late Mr. Burnett, M.E."† The cost of land carriage to the shipping-point on the Mokihinui River prevented this undertaking from being successful. Mining therefore came to a stop, and was not resumed in the district until 1880 or thereabouts.

Early in 1872 a mine called the Albion was opened near Crane's Cliff at the point where Mine Creek joins the Ngakawau River.‡ The workings were in friable coal dipping at a steep angle, and the cost of transport was high, the coal being shipped in small vessels which had difficulty in entering and leaving the Ngakawau. The Albion Company therefore soon suspended operations, with the intention of resuming work when railway connection with Westport was established.§

At the Waimangaroa River mining began on faulted much-crushed blocks of coal in 1874 or earlier. W. M. Cooper and R. B. Denniston in various reports‖ mention drifts worked by Rhodes and party, by Sim and Mulholland, and by Roche. Sim's drift developed a few years later into the Wellington Mine.

In the year 1873 W. M. Cooper and R. B. Denniston began the topographical and mineral surveys, of which some details are given on page 4. These surveys were the basis of Sir James Hector's estimate¶ that 100,000,000 tons of coal were available in the area between Westport and Ngakawau, and of various later estimates (see Chapter VI).

In 1877 the Wellington Coal Company first placed coal on the market, and in the following year had a recorded output of 1,468 tons. The coal was extremely friable, and the company therefore erected six coke-ovens, in which a good class of coke is said to have been made.** During 1878–79, according to the Warden, a large amount of coke was produced, but the tonnage is apparently not officially recorded.

In 1878 the Westport Colliery Company (later the Westport Coal Company) was formed with the object of amalgamating the numerous existing coal leases.†† This the promoters were largely successful in doing, and the construction of haulage inclines, roads, and other surface works was begun or continued. The first workings of the company were situated near Denniston, and were originally known as the Fisher Mine, which in 1880 was renamed the Banbury.‡‡ At the end of 1878 the mine is recorded

* "Abstract Report on the Progress of the Geological Survey of New Zealand during 1866–67," 1867, p. 11. See also Rep. G.S. during 1866–67, No. 4, 1868, p. 24

† Rep. G.S. during 1886–87, No. 18, 1887, p. 156.

‡ Rep. G.S. during 1871–72, No. 7, 1872, p. 137.

§ Report of Westport Colliery Reserves Commission, A.-3, 1876, p. 117.

‖ E.-3, 1875, App. I, p. 93; E.-9, 1875, pp. 2, 17; A.-3, 1876, p. 117.

¶ Rep. G.S. during 1874–76, No. 9, 1877, Progress Report, p. xii.

** S. H. Cox: "Report on the Coal-mines of New Zealand inspected during the Past Year." Rep. G.S. during 1877–78, No. 11, 1878, p. 175.

†† Westport Coal Committee (Report of), I.-6, 1882, p. 17.

‡‡ In Mines Report, C.-3, 1887, p. 4, and in Mines Report (not numbered), 1887, p. 195 (Coal-mines of New Zealand), G. J. Binns states that the Banbury Mine was then known as the Coalbrookdale. So far as the writers know, however, the name "Coalbrookdale" refers only to the area south of Burnett's Face, and was never (except in error) applied to the Banbury Mine.

as having a total output of 1,190 tons, whilst in 1879 2,600 tons were mined.* The Westport Colliery Company, having met with many financial and other troubles, was in September, 1881, reconstructed under the now well-known name of the Westport Coal Company.† The new company extended its haulage line towards Coalbrookdale, and at the end of 1884 had the creditable total output of 189,412 tons.‡

In 1880 the recently opened Mokihinui Mine sent away 500 tons of coal, but found conditions unfavourable, and ceased operations at the end of the year.§ The Wellington Coal Company became merged with the Koranui Company, which, having acquired a continuous lease on the 1st January, 1879, constructed a long incline tramway on the southern slope of Mount Frederick, and in or about 1883 began active coal-mining operations.

In 1885 the Mokihinui Coal Company began work, and at a later date a mile and a half of railway was constructed in order to connect the mine near St. Helens (as the locality is now called) with a wharf built on the Mokihinui River close to the present railway-station of Mokihinui, but for some years the company was occupied chiefly in prospecting and in extending its railway towards Coal or Parenga Creek. The Koranui Mine was bought by the Union Steamship Company, and in spite of many difficulties its output was greatly increased. At the end of 1886, however, the mine was sold to the Westport Coal Company, and since then has not been worked.

The old Albion Mine at Ngakawau was again taken up and worked on a small scale in 1888‖ and succeeding years by the Westport-Ngakawau (also called the Westport-Wallsend) Company, which proposed to build ovens for coking the soft and friable coal. In 1891, however, the company abandoned its Mine Creek workings, on account of the thinning of the seam to the dip, and the poor quality of the coal being won,¶ but prospected the higher-level portion of its ground, where some good coal-outcrops were found. The ill fortune of the Mokihinui Company was persistent, for after developing a 23 ft. coal-seam (with a maximum thickness of 30 ft.) in Coal Creek,** their newly acquired transport steamer, the "Lawrence," was in 1891 wrecked on the Mokihinui River bar, and, in addition, a bad downthrow fault was encountered in their dip workings. On the other hand, in 1892 the prospects of the mine were improved by the completion of the railway to Westport.

In 1888 the Waimangaroa Mine, operated by Messrs. Haylock and Young, began work†† on the south bank of the Waimangaroa River, opposite the old Wellington Mine, which was reprospected in 1890, and reworked during 1891. In these mines the coal was extremely friable, and the seams steeply tilted. Permanent success could hardly be expected, and in 1893 both undertakings were finally abandoned.‡‡

On the 28th November, 1891, the first shot in connection with the construction of the inclined tramway to the present Millerton-Mine Creek-Mangatini Coal-mine was fired at Granity.§§ Five years later this mine began to produce coal, and soon became one of the largest producers in the Dominion.

In 1893 the Westport-Cardiff Coal Company began operations near the present township of Seddonville, then known as Bayfeild's Flat, and in 1894 began to produce

* Mines Report, 1879, H.-16, p. 22; and Mines Report, 1880, H.-18, p. 18.
† I.-6, 1882, p. 17.
‡ Mines Report, 1885, C.-4, p. 13.
§ H.-13, 1882, p. 24, gives the production for 1881 as "nil."
‖ Mines Report, C.-2, 1889, p. 152.
¶ Mines Report, C.-3B, 1892, p. 5.
** Mines Report, C.-4, 1891, p. 208. Not improbably 23 ft. is a misprint for 32 ft.
†† Mines Report, C.-2, 1889, p. 152.
‡‡ Mines Report, C.-3B, 1894, p. 4.
§§ Mines Report, C.-3B, 1892, p. 6.

coal, though on a limited scale. The seam worked was 18 ft. and more in thickness, but in places contained so-called "stone-veins."*

The Mokihinui Coal Company continued operations for some years, but with indifferent success. In 1894 the Inspector of Mines (Mr. N. D. Cochrane) reported that numerous veins and bands of stone intersected the seam, whilst the coal itself was in places soft and of poor quality.† During this year two fires broke out in the mine but were effectually sealed off after some trouble. After being idle for some months, the mine was leased by a co-operative party of miners—the Knights of Labour—who worked it for some time during 1895. The Mines Reports do not state how long this interesting experiment lasted, but apparently the Mokihinui Company took over the colliery at the end of a few months, after the Knights of Labour had given it "a good trial."‡ Towards the end of 1896 all winning-work ceased, and somewhat later the Mokihinui Coal Company was presumably wound up, for the property ultimately came into possession of the Crown, as indicated in the next paragraph but one.

For some years the Westport-Cardiff Coal Company continued to increase its output, which in 1898 reached a total of 60,001 tons. During 1899 various difficulties were encountered, and in September the mine was temporarily closed down. On the 28th January, 1900, a fire was discovered in the main section of the mine, which was then sealed, and later flooded, or partly flooded, with water in order to extinguish the fire. These measures were not successful, and at the present time (1914) the coal is still burning. In May, 1900, the Westport-Cardiff lease was resumed by the Crown,§ and now forms part of the Seddonville State Coal Reserve.

In June, 1900, a party of twelve miners, constituting the Westport Co-operative Coal Company, took over the Mokihinui Mine from the State, and for a short period worked the Big Face section with some success. Owing to crushing of pillars, however, the old fire-stoppings gave way, thus allowing the fire to make progress. After vainly attempting to seal off the fire, the party turned its attention to the dip workings in the Hut section, and later to some ground situated to the westward, in Cascade Creek valley, which adjoined the State Coal Reserve. The Hut section was found to be limited by faults, whilst the coal in the Cascade Creek section was thin and not of good quality. Towards the end of 1904 the co-operative party ceased work. It was then reconstructed with six shareholders, and during the first six months of 1905, 1,146 tons of coal were produced. The coal, however, was friable, and could not be sold at a profitable price. The mine was therefore abandoned by the lessees, and thus reverted to the Crown.‖

In 1901 the Government set about the development of the ground formerly held by the Westport-Cardiff Coal Company as a State enterprise. A new section, the "Cave Area," was opened up under the name of the Seddonville Colliery. In 1904 the mine reached a producing-basis, the output in that year being 33,308 tons. Though the "Cave Area" and adjoining territory showed many thick outcrops of hard coal, yet actual working disclosed extensive patches of soft or friable coal, some of which was also dirty. The mine was never really successful, and at the end of April, 1914, owing to the almost complete exhaustion of the hard coal in sight and the utter impossibility of profitably mining the friable coal, was closed.

The Westport-Stockton Coal Company, formed in order to work coal-bearing leases some miles south-east of Millerton, began extensive development-works in

* See Mines Reports, C.–3B, 1894, and following years.
† C.–3B, 1895, p. 4.
‡ C.–3B, 1897, p. 5.
§ Mines Reports, C.–3A, 1901, p. 2.
‖ For the particulars contained in this paragraph see Mines Reports, C.–3A, 1901, 1902, 1903, 1904, 1905 and 1906.

December, 1905, and formally opened their mine on the 6th October, 1908. For two or three years a large output was maintained, but the areas at first worked being small and much of the coal friable, the production fell away. Recently a large field of coal lying in the eastern part of the company's lease has been tapped, and appears likely to yield a considerable output of coal for many years.

North-east of Kiwi Compressor (Burnett's Face district) is a coal-bearing area of approximately 1,200 acres commonly known as Cook's or Westenra's Lease. This ground has been held for a number of years by various persons, but very little prospecting and development-work has been done thereon.

So far mention has been made only of mines working the bituminous coal of the Denniston-Seddonville district. There are, however, several lignite-mines near Charleston, as well as brown-coal mines in the Buller Valley near Inangahua Junction, and therefore somewhat outside the area now under description.

The first record of coal-mining at Charleston found by the writers is the mention of the Charleston Coal-mine as being worked opencast in 1880*, but it is certain that coal-mining began long before this time. In 1893† the Waitakere and Powell's coal-mines are recorded as having been at work for about twenty years. At one time and another a number of pits have been worked by open-face methods, and in 1913 three were in operation. At present coal-mining in the Charleston district is of little importance. It is understood, however, that Messrs. Bowater and Bryan, who have taken up a large area under lease, intend to extend their tram-line from its present terminus south-east of Cape Foulwind to Charleston, in the expectation that the lignite may be introduced to a larger market.

Coal-mining Leases.

All or practically all the coal-mining in the Westport district is on land leased from the Crown as owner; a nominal rental of 2s. 6d. per acre, merging into a royalty of 6d. per ton, is charged. It may be of interest to mention a few details which have been collected by the writers. It would be useless, however, to attempt to deal with the numerous early leases, all of which, by surrender, forfeiture, or changes in the terms, have become obsolete.‡

Mokihinui Coal Company.—On the 1st July, 1885, this company was granted a lease of 160 acres for a term of forty-two years, and on the 1st July, 1888, a second lease of 640 acres for a term of sixty-three years. In 1892 a new lease of 960 acres was applied for.

Westport-Cardiff Coal Company.—The original lease of 320 acres was acquired in 1885 by Mr. A. D. Bayfeild, and was for forty-two years from the 1st July of that year. No work was done on this lease, which in 1889 was incorporated in a fresh lease of 1,800 acres. This the Government took over on the 23rd May, 1900.

Westport-Ngakawau Coal Company.—This company's lease of 3,118 acres, which included the old Albion Mine, was dated from the 1st January, 1889. The Westport-Stockton Coal Company now holds a considerable portion of the ground.

Wellington Coal Company.—This company's lease was for a period of forty-two years from the 1st January, 1876.

Koranui Company.—A lease, dating from the 1st January, 1879, was issued to this company in 1880. In 1881 the Wellington lease was acquired, and in 1885 both leases were transferred to the Union Steamship Company, which had been granted,

* Mines Report, H.-14, 1881, p. 8.
† Mines Report, C.-3, App. III, 1893, p. iv.
‡ Particulars concerning some of these will be found in "Leases in Buller Coal Reserve (Return of)," I.-6, 1889; in "Buller Reserves Coal-mining Leases," C.-8, 1887, &c.

on the 27th March, 1885, a lease of an adjoining block for thirty-seven years from the 1st January, 1884. The leases were acquired by the Westport Coal Company in 1886, but were soon after abandoned.*

Westport Coal Company.—The leases originally held by this company had been acquired at various times, and must have been of a varied nature as regards their dates and the periods for which they were held. The company, however, applied for and in 1888 was granted new leases of its Denniston properties. At the end of that year the leases held by the Westport Coal Company were for 2,479 acres in Kawatiri Survey District for a term of ninety-nine years, dating from the 1st January, 1888, and for 2,951 acres in the Ngakawau Survey District, also for a term of ninety-nine years, but dating from the 1st January, 1882.

At the present time (1914) the principal leases are as follows:—

	A.	R.	P.	A.	R.	P.
Westport-Stockton Coal Company (about)				1,999	3	20
Westport Coal Company:—						
(*a.*) Millerton	2,951	2	7			
(*b.*) East of Denniston (Burnett's Face, Kiwi Compressor, &c.)	1,563	3	36			
(*c.*) South-east of Denniston (Coalbrookdale, Cascade Creek, &c.)	915	2	2			
(*d.*) New extension (east of Denniston leases)	751	3	7			
				6,182	3	12
Cook's or Westenra's lease				1,199	2	9
With these may be included— Seddonville State Coal Reserve				6,503	2	38
Total				15,855	3	39

Buller Coalfield Reserve.

In 1863 the Nelson Provincial Council passed an Act known as the Buller Reserves Administration Act, which probably, as the writers assume, reserved land for coal-mining purposes in the Westport district.† This and amending Acts were repealed by the Westland and Nelson Coalfields Administration Act, 1877, which declared that an area of approximately 114,000 acres, known as "The Buller Coalfield Reserve," and an area of 73 acres in the town of Westport known as "The Colliery Reserve," were Crown lands, and provided that all revenue derived from these areas should be expended on the Westport-Ngakawau railway. At the present time these reserves, by virtue of the Westport Harbour Board Act, 1884, form endowments to the Westport Harbour Board. The boundaries of the Buller Coalfield Reserve, as described by the Third Schedule of the 1877 Act, are approximately shown by the maps accompanying this bulletin.

Mining Methods.

The coal-mining methods of the Westport field are similar to those of the Greymouth district, of which an account is given on pages 23–26 of Bulletin No. 13, and therefore need not here be described at great length. Owing to the coal-seams being more

* This is an inference made by the writers from the fact that these leases were not included in the new leases granted to the Westport Coal Company in 1888.

† See *Nelson Gazette*, vol. xi, No. 9, 21st April, 1863, p. 32.

or less variable in dip, strike, thickness, and quality, subject to "rolls," intersected by numerous faults and stream-valleys, &c., the workings are in many places necessarily somewhat irregular.

The coal is won in the first place from bords, 16 ft. to 18 ft. in maximum width, driven on the average 1 chain apart. They are sometimes broken away with a width of 12 ft., but in many cases are begun with the full width of 18 ft. The bords are connected at intervals of 1 chain by cut-throughs, ends, or stentons, which are usually of the same widths as the bords. Thus the pillars are normally 48 ft. square, but in practice there is considerable variation. Where the seam is thick head coal is dropped, usually simultaneously with the working of the pillars, which are removed in "lifts," or slices. In the Mangatini section of the Millerton Mine, where the coal reaches 50 ft. and more in thickness, the pillars are first split, then a small slice or lift is taken off each end. The top or head coal is then shot down (blasting-powder being the explosive), and after the broken coal has been filled, another lift is removed in the same way as before. Great falls of coal often take place, and a pair of miners have been known to fill coal for several weeks from one place without ever having to break coal from the face. This process of working the pillars is continued until it is deemed unsafe to proceed any further. In very thick seams there may be two or even three drifts one above the other, but there cannot well be more than one set of bords and of pillar workings. Necessarily a large percentage of the coal cannot be recovered from those portions of the seams with thickness exceeding, say, 16 ft. or 18 ft. Only by a filling-in method could all the coal be removed without frequent loss of life, but the cost of such a system renders it impracticable for the Westport district or any other locality in New Zealand until the selling-price of coal increases very considerably.

The necessary cutting and holing at the coal-faces is usually done by manual labour alone, and the coal is then broken down by mean of blasting-powder. As far back as 1897 the Westport Coal Company introduced electrically driven pick holing-machines into the Ironbridge Mine (Burnett's Face), and compressed-air machines into the Millerton Mine. In 1899 pick machines driven by air were used throughout the Coalbrookdale Mine, and were supplementing and displacing the electrical machines in the Ironbridge Mine. For some years the bulk of the coal was mined with the aid of pick machines actuated by compressed air, but these apparently gradually fell into disuse, and were not replaced by new and more efficient types.*

In the Westport-Stockton Mine electrically driven Sullivan holing-machines were employed for several years, but have not been in use for some time, and the coal is now being mined in the old-fashioned way.†

The coal broken at the faces is filled into trucks or "tubs" with iron or steel bodies holding from 15 cwt. to 30 cwt. (Westport-Stockton Mine). From the faces the coal is conveyed to the main haulage-roads by manual labour, by jigs, and by horses. The unweildy trucks employed in the Westport-Stockton Mine are quite unsuitable for hand-trucking, and on this account the haulage from the winning-faces to the level roads is accomplished almost entirely by means of flexible steel ropes, actuated by small electrically-driven winches. In the same mine small electric locomotives weighing 13,000 lb., with a drawbar pull of 2,500 lb., are employed for haulage on some of the subsidiary roads.‡

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* For references to coal-cutting machines, see Mines Reports, C.-3A, 1898, 1899; C.-3, 1899, p. 176; and C.-3A of succeeding years.

† Letter from Mr. James Newton, Inspector of Mines, dated 27th May, 1914.

‡ Mines Report, C.-3A, 1910, p. 9.

Transport on Main Roads.

The transport arrangements of the various bituminous coal-mines are on so large a scale and present so many interesting, though perhaps not novel, features that some description of them may well be given here.

Westport Coal Company's Denniston Collieries.—The numerous sections of the Denniston mines, worked more or less independently of one another—for example, the Coalbrookdale Mine, with its subsections Cascade and Whareatea, Ironbridge Colliery, Kruger's section, Deep Creek section, &c.—deliver their coal by means of a branching system of endless ropes to a point near the "Wooden Bridge," at Burnett's Face. Hence a single endless rope with a capacity of 1,500 tons per shift of eight hours takes all the coal through a tunnel, and thence on the surface to the tippling-plant at Denniston. Since on the whole the grade is against the coal from the various mines to Denniston, engine-power is necessary at a number of points to actuate the endless ropes. In 1913 there was in all seventeen miles of endless rope in operation.

After being weighed, tipped, and if necessary screened, the coal passes into large bins, which deliver it through doors operated by hydraulic machinery into railway-trucks holding eight tons of coal each. These are lowered by wire rope down a wonderful self-acting incline to the locomotive railway-line at Conn's Creek. This incline is in two sections, the upper of which, according to Mr. H. A. Gordon, is 34 chains in length, with a fall of 801 ft., and a maximum grade of 1 in 1·34. The lower incline is 49 chains in length, with a fall of 870 ft., and a maximum grade of 1 in 2·02. Powerful hydraulic brakes are employed in order to control the speed of the descending truck, which is naturally only partly counterbalanced by the ascending truck. The capacity of the incline is at least 1,000 tons per shift of eight hours.*

Westport Coal Company's Millerton Colliery.—The Millerton Mine has three main sections—namely, Millerton to Mine Creek, Mine Creek to Mangatini, and Mangatini. These sections being situated one beyond the other, the haulage system is not so complex as that of the Denniston mines, and consists merely of a series of self-acting endless ropes, controlled by powerful hydraulic brakes, the grade being everywhere in favour of the load except for a short distance in the Mine Creek - Mangatini section, where there is a basin or "swallow" in the coal-measures. From Mine Creek to near the Millerton station the haulage-road is driven on a uniform grade in granite underlying the coal-measures, and therefore possesses an admirable degree of permanency and freedom from danger. From the Millerton station the coal is lowered down a steep incline with two tunnels, one in coal-measures and the other in granite, to the tippling, screening, and bin plant at Granity, where it is loaded into railway-trucks. The distance from the Mangatini section to Granity is approximately four miles, and the fall considerably over 2,000 ft.

Westport-Stockton Coal Company's Mine.—The Westport-Stockton Coal-mine has a most interesting transport system, which is in large measure operated electrically. From the D and C tunnel sections, and the upper part of B tunnel section, the coal trucks or tubs are lowered by self-acting endless-rope inclines to a station in B tunnel. The lower of these endless ropes is controlled by an electrically operated brake, the upper by a powerful hand-brake. From the station in B tunnel electric locomotives weighing 40,000 lb., with a drawbar pull of 7,500 lb., transport the coal-trucks to

* References: Mines Reports, C.-3, 1895, p. 168; C.-3, 1899, p. 175; *Mines Record*, vol. iv, 1900–1, p. 144.

Plate V.

Upper Part of Westport Coal Company's Incline, Granity to Millerton.

Geol. Bull. No. 17.] *[To face page 38*

Swampy Flat, a distance of approximately two and a quarter miles. The average grade in favour of the load being 1 in 21·4, a brake car is necessary to supplement the locomotive brakes. From Swampy Flat or "Top Brake" station, which is approximately 1,050 ft. above sea-level (barometric observation), the coal-tubs are lowered with the assistance of an hydraulic brake down a 40-chain endless-rope incline with an average grade of 1 in 6·7, and a maximum grade of 1 in 5 to the "Middle Brake." Here is another endless-rope incline, a few chains shorter in length, with an average grade of about 1 in 4, and a maximum grade of 1 in 3. At the foot of this incline is a sub-station, whence the tubs are drawn in rakes by a main and tail rope system operated by an electrical winch through a 28-chain tunnel to the tippling-plant and bins at Ngakawau.*

The new workings in the east section of the Westport-Stockton lease are connected with the main haulage-station in B tunnel by an electric-locomotive line, which after crossing the Mangatini Creek enters a tunnel driven thence to the station.

Seddonville State Coal-mine.—During the time the Seddonville Colliery was in operation the coal was drawn from the mine to the bins by means of an endless rope which was almost, but not quite, self-acting. This at one time extended across Chasm Creek into the Bridge section, but during 1911 and 1912 the terminal was in the tunnel on the north side of Chasm Creek. From this point the grade was slightly against the load for some distance. The haulage-tunnel then entered granite, with a grade in favour of the load. From the northern mouth of the tunnel there was a steep downhill grade for some distance, and the road then became nearly flat, except for a few chains near the bins, where the grade was again in favour of the load.

Drainage.

The various mines are all "level-free"—that is, they may be drained by adits, but owing to the varying dip of the coal strata some difficulties in the way of drainage arise. Several special drainage adits have been driven in connection with the Westport Coal Company's mines at Coalbrookdale, Kiwi Compressor, and Mine Creek. These discharge a large quantity of water, especially in wet weather, when much of the rainfall enters the mine-workings through cracks caused by the subsidence of the strata overlying worked areas. In small blocks, where either coal is being worked to the dip, or which are basins ("swallows") not worth the expense of draining by a special adit, pumps driven by steam, compressed air, or electricity are installed.

Output of Coal.

The yearly and total output of the various bituminous coal-mines in the Buller-Mokihinui Subdivision is shown by the table on the next page. Some of the data relating to the smaller mines in their earlier years are evidently approximate only, whilst it has not been found possible to ascertain the output of the various mines worked on a small scale prior to 1877, and statistics for the Charleston district, where lignite has been mined for many years, are almost wanting. These omissions, however, do not seriously affect the totals. The compilation of the table was rendered possible only by the statistics of production which have been carefully collected by the Mines Department during the past thirty-five years.

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* Most of these particulars are from Mines Reports, C.-3A, 1907, 1908, 1909, and 1910.

TABLE SHOWING YEARLY AND TOTAL OUTPUT OF BITUMINOUS COAL-MINES.

Year.	Production for Year, in Tons.	Total to End of Year, in Tons.	Production for Year, in Tons.	Total to End of Year, in Tons.	Production for Year, in Tons.	Total to End of Year, in Tons.	Production for Year, in Tons.	Total to End of Year, in Tons.	Production for Year, in Tons.	Total to End of Year, in Tons.	Production for Year, in Tons.	Total to End of Year, in Tons.
	Wellington Mine.		*Westport Company's Denniston Mines.*									
1878	1,468	2,263	1,190	1,190	..	..	..	..	..	..	..	..
1879	1,260	3,523	2,600	3,790	..	..	*Mohikinui Mine (No. 1).*		..	..	..	..
1880	880	4,403	3,892	7,682	..	..	500	500	..	..	..	..
1881			24,198	31,880	..	..			..	..	..	..
	Koranui Mine.											
1882	196	196	48,348	80,228	..	..	..	..	..	..	..	..
1883	3,300	3,496	34,997	115,225	..	..	..	..	..	..	..	..
1884	5,989	9,485	74,187	189,412	..	..	*Mokihinui Mine (No. 2).*		..	..	..	..
1885	30,539	40,024	47,470	236,882	..	..	275	275	..	..	..	..
1886	44,170	84,194	75,609	312,491	..	..	150	425	..	..	..	..
											Westport-Ngakawau Mine.	
1887	..	..	115,942	428,433	..	..	300	725	..	..	1,568	1,568
1888	..	..	130,170	558,603	..	..	316	1,041	*Waimangaroa Mine (Haylock and Young's).*		1,873	3,441
1889	..	..	163,015	721,618	..	..	2,250	3,291	200	200	..	..
1890	*Wellington Mine (reopened).*		160,240	881,858	..	..	4,206	7,697	3,987	4,187	..	..
1891	1,035	1,035	192,606	1,074,464	..	..	4,540	12,037	7,830	12,017	..	..
1892	1,264	2,299	198,466	1,272,930	..	..	3,056	15,039	5,290	17,307	..	..
									Westport-Cardiff Coal Co.			
1893	..	..	223,701	1,496,631	..	..	2,076	17,169	500	500	..	..
1894	..	..	215,770	1,712,401	..	..	10,742	27,911	4,500	5,000	..	..
1895	..	..	183,745	1,896,146	..	..	5,626	33,537	32,702	37,702	..	..
					Westport Company's Millerton Mine.							
1896	..	..	190,975	2,087,121	20,543	20,543	9,537	43,074	40,431	78,133	..	..
1897	..	..	184,376	2,271,497	59,240	79,783	..	43,074	54,280	132,412	..	..
1898	..	..	192,851	2,464,348	87,269	167,052	..	43,074	60,101	192,514	..	..
1899	..	..	202,514	2,666,862	125,417	292,469	..	43,074	34,927	227,441	..	..
1900	..	..	211,357	2,878,219	158,129	450,598	10,092	53,166			..	..
1901	..	..	226,193	3,104,412	207,379	657,977	20,257	73,423	*Seddonville State Colliery.*		..	..
1902	..	..	243,336	3,347,748	276,750	934,727	6,287	79,710	120	120	..	..
1903	..	..	251,607	3,599,355	313,584	1,248,311	1,000	80,710	2,017	2,137	..	..
							Mokihinui Co-operative Co's.					
1904	..	..	248,833	3,848,188	285,175	1,533,486	2,457	83,167	33,808	35,945	..	..
1905	..	..	261,012	4,109,200	239,219	1,772,705	1,146	84,313	46,085	82,030	..	..
1906	..	..	307,555	4,416,755	264,001	2,036,706	..	..	36,713	118,743	..	..
1907	..	..	313,005	4,729,760	297,754	2,334,460	..	..	35,436	154,179	*Westport-Stockton Mine.*	
1908	..	..	296,617	5,026,377	316,601	2,651,061	..	..	55,231	209,410	3,267	3,267
1909	..	..	348,335	5,374,712	212,474	2,863,535	..	..	67,935	277,345	89,675	92,942
1910	..	..	347,719	5,722,431	268,816	3,132,351	..	..	62,714	340,059	151,951	244,893
1911	..	..	323,368	6,045,799	299,642	3,431,993	..	..	60,045	400,104	87,236	332,129
1912	..	..	298,636	6,344,435	329,430	3,761,423	..	..	72,693	472,797	125,031	457,160
1913	..	..	241,375	6,585,810	292,576	4,053,999	..	..	51,894	524,691	93,315	550,475

The following table shows the total output for the district, year by year, since 1877, the few returns available from the Charleston lignite-pits being omitted, so that the table shows output of bituminous coal only :—

Year.	Output for Year.	Total Output to Date.	Year.	Output for Year.	Total Output to Date.
	Tons.	Tons.		Tons.	Tons.
1877	795	795	1896.. ..	261,486	2,341,015
1878	2,658	3,453	1897.. ..	297,896	2,638,911
1879	3,860	7,313	1898.. ..	340,221	2,979,132
1880	5,272	12,585	1899.. ..	362,858	3,341,990
1881	24,198	36,783	1900.. ..	379,578	3,721,568
1882	48,544	85,327	1901.. ..	453,829	4,175,397
1883	38,297	123,624	1902.. ..	526,493	4,701,890
1884	80,176	203,800	1903.. ..	568,208	5,270,098
1885	78,284	282,084	1904.. ..	570,273	5,840,371
1886	119,929	402,013	1905.. ..	547,462	6,387,833
1887	116,242	518,255	1906.. ..	608,269	6,996,102
1888	130,486	648,741	1907.. ..	646,195	7,642,297
1889	167,033	815,774	1908.. ..	671,716	8,314,013
1890	170,306	986,080	1909.. ..	718,419	9,032,432
1891	206,011	1,192,091	1910.. ..	831,200	9,863,632
1892	208,076	1,400,167	1911.. ..	770,291	10,633,923
1893	226,277	1,626,444	1912.. ..	825,790	11,459,713
1894	231,012	1,857,456	1913.. ..	679,160	12,138,873
1895	222,073	2,079,529			

The production of individual mines, so far as ascertainable, is shown by the following table :—

PRODUCTION OF BITUMINOUS COAL-MINES.

——	Prior to 1913.	In 1913.	Grand Total.
	Tons.	Tons.	Tons.
Wellington Mine (1877–80)	4,403	..	4,403
Wellington Mine (1891–92), (reopened)	2,299	..	2,299
Koranui Mine (1882–86)	84,194*	..	84,194
Waimangaroa Mine (Haylock and Young's), (1889–92)	17,307	..	17,307
Westport Coal Company's mines near Denniston (1878)	6,344,435	241,375	6,585,810
Westport Coal Company's Millerton Mine (1896) ..	3,761,423	292,576	4,053,999
Mokihinui No. 1 Mine (St. Helens), (1880)	500	..	500
Mokihinui No. 2 Mine (Lower and Upper Mokihinui), (1885–96)	43,074†	..	43,074
Mokihinui No. 2 Mine (Upper Mokihinui), (1900–5) ..	41,239‡	..	41,239
Westport-Cardiff Mine (1893–99)	227,441	..	227,441
Seddonville State Mine (1902)	472,797	51,894	524,691
Westport-Stockton Mine (1908)	457,160	93,315	550,475
Westport-Ngakawau (1889–90)	3,441	..	3,441
	11,459,713	679,160	12,138,873

* Does not include Wellington Mine (4,403 tons). There is a discrepancy of 3 tons in the official figures.

† 1,041 tons produced in the years 1885 to 1888 may have been from neighbourhood of Seddonville or St. Helens ; the rest of this production was probably all from Coal Creek (Upper Mokihinui).

‡ Production all from Coal Creek mines (Upper Mokihinui).

The production of various small mines worked at Mokihinui prior to 1880 and that of the Albion Mine at Ngakawau are unknown. The lignite-production of the subdivision is not fully recorded in any official publication. The only figures available show that the Waitakere Mine at Charleston from 1893 to 1899 had an output of 868 tons.

The individual outputs of bituminous coal from the various mines during the three years 1911, 1912, and 1913 are as follow:—

Colliery.	1911.			1912.			1913.		
	Coal.	Slack.	Total.	Coal.	Slack.	Tons.	Coal.	Slack.	Total.
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
Seddonville State ..	25,225	34,820	60,045	56,161	16,532	72,693	30,137	21,757	51,894
Westport-Stockton ..	42,100	45,136	87,236	79,971	45,060	125,031	66,343	26,972	93,315
Millerton	245,144	54,498	299,642	279,613	49,817	329,430	243,460	49,116	292,576
Denniston (Ironbridge, Coalbrookdale, &c.)	240,832	82,536	323,368	229,352	69,284	298,636	190,736	50,639	241,375

It is evident that the correct proportion of slack to round coal, nuts, &c., is not given by the above table. The discrepancies are presumably due to the exigencies of trade affecting the quantity of fuel subjected to screening.

The Mines Report for 1913 gives the total production of the Buller coalfield as 12,157,911 tons, or 19,038 tons more than that given in the tables. This difference is due to the Mines Report figures including 868 tons from Charleston (as above), 8,153 tons from the Buller Gorge mines (Whitecliffs and Rocklands), 4,437 tons from Three-channel Flat mines, 1,712 tons from Longford mines,* and 4,263 tons from mines at Boatman's (Capleston). On the other hand, the 500 tons produced by the Mokihinui No. 1 Mine in 1880 does not appear to be included in the total. Clerical errors or misprints in the records account for the remaining discrepancy of 103 tons.

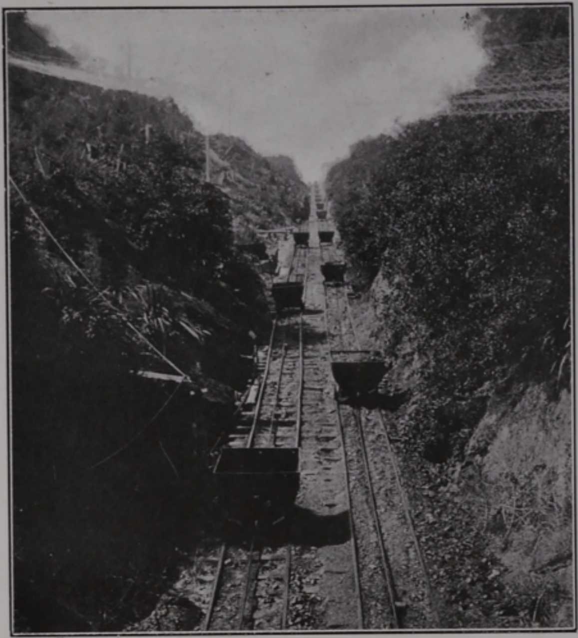
Future Prospects of Coal-mining.

In Chapter VI it is shown that the known blocks carrying workable seams of bituminous coal do not together constitute a large area. Of these blocks those that are readily accessible and contain the best coal have already been developed and worked to a considerable extent. For future development there remain outside existing leases now being actively worked only Cook's lease, the somewhat problematical Blackburn field, the summits of Mounts Frederick and William, Charming Creek, and a few other small areas. In addition there is the possibility of the low country near Westport containing a large amount of workable bituminous coal, together with overlying lignite. Until, however, extensive boring has been done no great weight can be given to the potentialities of the Westport flats.

After a careful consideration of all the circumstances, the writers are forced to conclude that the bituminous coal-production of the Westport district will but slowly increase during the next ten or fifteen years. An increase in selling-price will stimulate production, but competition with Australian coal will prevent prices being raised to such a point as greatly to increase the rate of production. If, then, the Westport flats are found to contain workable coal they will be developed, but by that time the production of coal on the high levels will have reached its maximum, and, as indicated by the estimates in Chapter VI, the life of the known bituminous coalfield is not likely greatly to exceed fifty years, even when decidedly optimistic assumptions are made.

As years go by, the brown coal and lignite of the subdivision will be mined on a considerably larger scale than at present. The deposits of these classes of coal within

* Near Murchison.



LOWER ENDLESS-ROPE INCLINE, WESTPORT–STOCKTON COAL COMPANY.

ELECTRIC LOCOMOTIVE BRINGING RACE OF LOADED TUBS FROM WESTPORT-STOCKTON COMPANY'S MINE TO TOP OF INCLINES.

 [*To face page 42.*

the subdivision are somewhat limited, but immediately adjoining its eastern boundary is the Inangahua coalfield which probably contains extensive seams of brown coal. The natural outlet for the bulk of this coal is Westport, and therefore much of it may be considered as within the Westport district, though not included in the area now being described.

Conservation of Coal Resources.

The proper utilization or conservation of the Dominion's coal resources is an important matter to which attention has repeatedly been called during the past few years. It is now well known to those who have seriously considered the question that in New Zealand the proved supplies of coal, more especially of bituminous coal, are decidedly limited, and will approach exhaustion within one hundred years, or at most one hundred and fifty years, from the present time. There is, however, a reasonable prospect that important discoveries of brown coal and lignite will be made in the future, and the life of New Zealand coalfields thus prolonged. As regards bituminous coal the outlook is unfortunately less hopeful. It is therefore obvious that every means for the conservation of this class of fuel, which is almost indispensable to the mercantile marine and the navy, ought to be employed.

The reader may here be reminded that the known bituminous coal of New Zealand is almost wholly in the Greymouth and Westport districts, though there is a small proved field in the Collingwood district, and unknown but not large areas in central Nelson.* Elsewhere one of the writers has estimated that the proved and the probable bituminous coal of New Zealand amount to 374,000,000 tons, and 477,000,000 tons respectively. In the light of later knowledge it appears that these quantities rest to some extent on over-optimistic assumptions, and ought to be reduced rather than increased, especially in view of the fact that much of the coal is unmineable.

In Chapter VI the writers estimate that the Westport district contains approximately 110,000,000 tons of proved bituminous coal, not including the 13,000,000 tons already mined, but including coal which, though still in the ground, is for practical purposes irrecoverable. In addition, there is a moderate amount of probable coal, but it is hardly feasible to make even a rough estimate of the tonnage. Not even the roughest guess of the possible bituminous coal in the Westport flats and elsewhere can be made. It is not likely, however, that the unknown coal equals the proved coal in quantity, much less exceeds the latter, and unfortunately it is probably much less. Over small areas, where the conditions are favourable, two-thirds or even three-fourths of the coal can be and has been extracted. But if the leases are taken as a whole, then, unless present conditions alter very greatly, not more than one-half, or possibly little more than one-third, of the coal in the mining leases will be extracted before the mines reach the stage of commercial exhaustion. An immense amount of coal will then be irrecoverably locked up in the forms of roof and floor coal not mined from thick portions of the seams, of pillar stumps, of friable coal not mined because there would be a loss in so doing, of small isolated blocks which could not be economically reached by the transport roads, of thin portions of the seams (which would, however, be considered as of workable thickness in Europe and in most parts of the United States), of somewhat dirty coal (which in various parts of the world would be gladly accepted as fuel,) &c In addition a considerable amount of coal will have been consumed or ruined by underground fires.

It need not be supposed that this great loss of coal is the fault of the mining companies or of the officials responsible for the management. The blame, if any,

* Bituminous coal in thin seams occurs in the Paringa district (South Westland) and in a few other localities.

must justly fall on the body politic, which in all countries is as a whole apparently indifferent to the approaching exhaustion of natural resources, until, too late, an hour of awakening comes. The mining companies must, if possible, make a profit, or, at the least, working-expenses must be paid, otherwise capital will become exhausted and mining will perforce cease. As for the mining operations, these are conducted with skill and with due regard to the safety of the workmen, and little fault is to be found with the technical management in other respects.

Under present conditions, therefore, the loss of coal, however regrettable, is in the main unavoidable. Only by appreciably reducing the cost of placing the coal on the market, or by materially increasing the selling-price, will it become economically possible to mine a much larger proportion of the coal. In the future, necessity will undoubtedly compel the mining of much friable coal that to-day, or at least a few years ago, would be left, and for such coal the consumer will have to give a higher price than that which he is now willing to pay. In order to mine, say, 80 per cent. of the coal a filling-in system will be necessary where the thickness of the coal-seam exceeds 15 ft. or 16 ft. Such a method is apparently commercially impracticable, for filling-material is not easy to obtain over the greater part of the coalfield, and the additional cost would not be less than 5s. per ton of coal at the mine-mouth. Although filling-in would not be necessary over considerable areas, yet with an increased percentage of extraction there would be increased mining costs, and the small consumer, at any rate, would not escape without paying on the average 7s. or 8s. more per ton for his fuel.

From what has already been said it may be inferred that reductions in the cost of marketing the coal probably would not and should not be applied to reducing the cost of the coal to the consumer, but would, or, at any rate, should, be used to meet the increased cost of extracting coal that is now unprofitable to mine. Marketing-costs can to some extent be relatively lessened by the following methods:—

(1.) Combination amongst the producers, so that the trade in coal may be more uniformly divided, and other conditions tending to economy rendered possible. It is possible, however, that the elimination of competition may be prejudicial in the long-run to the best interests of the country.

(2.) Increasing the efficiency of the labour employed. There is only a moderate scope for improvement in this direction.

(3.) Some improvements in mine transport, machinery, methods of development, &c., are possible.

(4.) Railway and steamer freights may be lessened. Undoubtedly the profit in transporting coal is greater than the mining profit, and therefore there is some reason why transport charges should be reduced.

Though some reduction in working-costs may be effected by the methods suggested and by other means, yet, so far as the writers can see, the only way by which the loss of two-thirds of the coal now in the ground can be prevented is through a substantial rise of the selling-price, which will render profitable the extraction of all the coal where the seams are thick, enable thin coal to be worked, and make it worth while to construct haulage-roads into isolated blocks. With increased selling-value of the better coal the complete extraction of friable coal will also become economically possible. Apparently the only practicable method of increasing the selling-price of the coal is through a protective tariff, which will exclude foreign coal from the New Zealand market. Doubtless legislation will also be necessary in order to compel the lessees of coal-bearing areas to work coal which they may deem unprofitable, but which ought to be worked in the interest of the owners—that is, the general public.

Whether it is better to allow much coal to go to waste or, as an alternative, increase the price to the consumer, and thus both increase the cost of living and perhaps cripple various industries, is a question in political economy which the writers, fortunately for their peace of mind, are not called upon to solve; but it does seem necessary to state that such a dilemma awaits those who may endeavour to prevent the regrettable apparent waste of natural resources that is going on at the present time in New Zealand and in many other countries, to the great probable detriment of future generations.

To some extent the consumer can meet the probable future increase in the cost of his coal by making better use of it. There are possibilities in connection with using the coal for mechanical stokers, dust-firing, for suction-gas plants, &c. The friable coal may be coked, and the gases given off utilized in various ways. The briquetting of slack, though not successful with the Seddonville coal, has possibilities before it. Something in the way of improvement may also be accomplished by mixing the bituminous coal with other classes of coal, especially as a preliminary to briquetting. The greatest hope for the future, however, seems to lie in the establishment of power plants on the coalfields, whence energy may be electrically distributed.

As regards conservation in its narrow sense—that is, preservation of the coal for a future generation—little can be said beyond making the obvious suggestion that economy should be practised by the consumer, a matter of which he seldom requires to be reminded, though sometimes he errs from lack of knowledge. There is little need, however, for bituminous coal to be employed for household use away from the neighbourhood of the fields themselves. New Zealand has a relatively abundant supply of pitch and brown coals, which, if procurable at a reasonable price, are more suitable for household requirements than most bituminous coals. The use of the latter in New Zealand should be restricted as far as possible to purposes for which it is indispensable.

Utilization of Friable Coal and Slack.

One of the greatest difficulties in the working of the Westport coalfield is connected with the profitable disposal of the friable coal and slack. It is said that the district contains 5,000 acres of unmined friable coal in seams of from 5 ft. to 20 ft. in thickness. In addition, over 25 per cent. of the coal mined in the district is slack.* Some of the slack is used for bunkering purposes, but the market is limited. Some possible methods of using slack and friable coal have been mentioned above. A brief account of two other ways in which slack and friable coal have actually been utilized in the district—namely, by coking and by briquetting—may here be given.

Coking.—In a previous section the construction of coke-ovens by the Westport-Ngakawau and Wellington companies was mentioned, but of these no traces remain to-day. Recently the Westport Company has built six modern ovens with hydraulic discharger at Granity, and these have been in operation since August, 1911. The coke, however, has hitherto not been in great demand, though it is hard, of good appearance, and of the quality indicated by the analyses given in Chapter VI.

Briquetting. — Much consideration has been given to the briquetting of New Zealand coals, but nothing was done prior to 1907, when briquetting-works were established at Westport in order to deal with the slack coal from the Seddonville Colliery. The report of the Royal Commission of Mines, published in 1912, states that the cost of manufacture of briquettes was nearly 16s. 6¾d. per ton, of which 7s. 8d. was for pitch alone. Freight and other expenses amounted to 11s. 3½d., making a

* Royal Commission of Mines (Report of, &c.), C.-4, 1912, pp. 32, 33. There may be some exaggeration as regards the area of friable coal.

total cost of £1 7s. 9d. (*sic*)* per ton, as against an average selling-price of £1 1s. 9d. or thereabouts. Obviously the works could not be continued on this basis, and were therefore closed during 1912. Fuller information concerning briquetting may be obtained from the report mentioned above.† All that need here be said is that experimental work in the briquetting of New Zealand coal appears desirable, more especially in the matter of finding a substitute for the too expensive pitch employed in the Westport briquette-works.

(5.) Rock-quarrying.

The Westport Harbour Board at the time of its inception, about 1884, was faced with the difficulty of obtaining material suitable for the construction of retaining-walls and moles in connection with harbour-works. Some years before the Harbour Board had been formed it was proposed to utilize for harbour purposes the sandstone and grit blocks that plentifully strew the lower slopes of Mount Rochfort, and a branch railway was constructed from Fairdown to the foot of the mountain. Fortunately the project was soon abandoned, but whether any rock was actually transported the writers have not been able to ascertain.‡

It was also proposed to use the granite from the Buller Gorge for harbour purposes, but ultimately quarrying operations were begun on the Cape Foulwind limestone and granite. In 1886 three quarries were at work, and a railway-line had been made by the Harbour Board from Cape Foulwind to the western bank of the Buller River. At this time something like 500 tons of rock was being daily broken and transported to the western mole. Shortly after the river was bridged, and in 1888 the construction of the eastern mole was begun. A few years later the quarrying of limestone was discontinued, and attention confined to the granite. At the present time there are several faces, all of which, except one, front the shore-line south of Cape Foulwind. The rock being quarried is a coarse porphyritic granite, more or less gneissic, which in places is somewhat decomposed, and yields a large percentage of rubble. Elsewhere, however, the rock is moderately fresh, and blocks of large size may be obtained without difficulty.

Now that the State railway is open to the mouth of the Buller Gorge, reconsideration of the old project of quarrying the rock in that locality for harbour purposes may be suggested. The gneissic granite of the Buller Gorge is more uniformly hard than the similar rock at Cape Foulwind; but, on the other hand, it is doubtful whether it can be quarried as cheaply.

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* There is an error of 1d. in one of the items as printed.

† Royal Commission of Mines (Report of, &c.), C.-4, 1912, pp. 32–35, 152–60.

‡ A sketch by W. M. Cooper made in 1875, and published in "Westport Colliery Commission (Report of, &c.)," A.-3, 1876, shows a locomotive with train of empty trucks attached, on the line.

View looking down Buller Gorge, below Berlin's.

[*To face page 46.*

CHAPTER III.

OUTLINES OF PHYSIOGRAPHY AND GEOLOGY.

PHYSIOGRAPHY.

Introduction.

CENTRAL and western Nelson, together with a portion of North Westland, form a physiographic unit in which the major land-forms, though much modified by erosive agencies, are essentially conditioned by differential movements of the land, accompanied by extensive faulting. The unity of this area and its geographical isolation are recognized throughout New Zealand, and are embodied in the popular name of the "West Coast." The West Coast region is one in which block mountains with a meridional trend, and, to a less extent, *gräben* or rift-valleys, are conspicuous features.* Its complete physiographic investigation is a matter of the greatest interest, but, since the Buller-Mokihinui Subdivision covers only a small part of western Nelson, full treatment of the subject cannot here be attempted.

Main Surface Features.

Of the mountain-ranges that meridionally traverse the subdivision the chief are the Paparoa Range, with its extension north of the Buller known as the Papahaua† Mountains, and the Glasgow Range, continued north of the Mokihinui River by Mount Kilmarnock. Seaward of the mountains is a belt of lowland country, consisting partly of hilly ground and partly of a terraced coastal plain. In places bold precipices front the sea, whilst elsewhere low sandhills as a rule fringe the foreshore. Two notable rivers, the Buller (Kawatiri) and the Mokihinui, break through the mountain-chains in wildly picturesque gorges.

Highlands.

North of the Mokihinui River the most conspicuous elevation is the bush-covered Mount Kilmarnock (3,308 ft.), formed mainly of hornfels and granite. This mountain is really the northern part of an uplifted faulted area ("the Glasgow Block") which pitches so strongly to the north that just outside the north-east corner of the subdivision it merges into comparatively low hilly country covered by Miocene strata.‡

* See N.Z.G.S. Bull. No. 11, 1910, pp. 10–11; and J. Henderson, "On the Genesis of the Surface Forms and Present Drainage-systems of West Nelson," Trans., vol. xliii, 1911, pp. 306–315. N.Z.G.S. bulletins Nos. 3, 6, 12, and 13 may also be consulted.

† Also spelt "Papahua." The spelling adopted in the text is von Haast's.

‡ See N.Z.G.S. Bull. No. 11, 1910, pp. 2–10, 16–22, &c.

Structurally continuous with Mount Kilmarnock, but separated from it by the deep gorge of the Mokihinui River, is the Glasgow Range, prominent points of which are Mount Glasgow (4,600 ft.), and Mount Vaughan (3,857 ft.). Several unnamed peaks reach elevations of from 4,400 to 4,700 ft. The Glasgow Range is an uplifted block of granite, hornfels, and other rocks, which is bounded on its western side by a great dislocation—the Glasgow fault of the maps. The structure on the eastern margin, which is everywhere outside the subdivision, is not known. South of Lyell, where it is joined by the nearly parallel Lyell Range, the Glasgow Range is obliquely intersected by the Buller River, and its continuation, which forms the eastern side of the Inangahua Valley, is then called the Brunner Range.

Besides being completely cut through by the Mokihinui and Buller rivers, the Glasgow Range is deeply dissected by minor streams. For several miles south of Mount Glasgow it has an extremely rugged narrow crest of serrate appearance. Here also signs of glacial action in the form of cirques, U-shaped valleys, and rock-basins are not wanting. Although the stage of dissection is mature, the geological youth of the range is attested by the involvement of Eocene and Miocene rocks in the Glasgow fault.

The highest points in the subdivision are found in the northern part of the Paparoa Range, which extends from the neighbourhood of Greymouth to the Buller Gorge, whence it is structurally continued by the Papahaua Mountains. As seen from Westport the most prominent peaks are Mount Kelvin (5,100 ft.), and Mount Buckland (4,300 ft.). The rocks forming the Paparoa Range are mainly granite and gneiss, which within the subdivision are flanked and to some extent overlain by breccias, conglomerates, mudstones, limestones, and sandstones of much younger (Tertiary) age.

The Papahaua Mountains may be described as forming a distorted plateau consisting of granite, gneiss, and Palæozoic sedimentary rocks, capped in most places by Tertiary coal-measures. The principal summits are Mount Rochfort (3,382 ft.), Mount William (3,482 ft.), Mount Frederick* (3,621 ft.), and Mount Augustus (3,311 ft.). The Mount William Range, which forms part of the Papahaua Mountains, owes its existence to strong upthrow on the eastern side of a dislocation known as the Mount William fault, and is structurally a miniature replica of the Glasgow and Paparoa ranges.

From a tectonic point of view the Paparoa-Papahaua Range is a long, faulted block that corresponds in many respects to the Glasgow Range. The eastern boundary of this earth-block is the Glasgow fault, while its western limit is another great dislocation, the Kongahu or Lower Buller fault. The intervening area, as viewed in and near the subdivision is tilted to the east, and, as a result, a distinct depression marks its eastern margin. South of the Buller this depression, which may be called the Inangahua *gräben* or trough, becomes very prominent. North of Mount Augustus the Papahaua portion of the block has on the whole a strong pitch to the north, so that, as with the Mount Kilmarnock extension of the Glasgow Range, the upland character lessens in that direction, and north of the Mokihinui River in great measure disappears. Owing to the convergence of the Lower Buller and Glasgow faults, the Papahaua sub-block also greatly decreases in width towards its northern extremity.

The structure of the southern part of the Paparoa Range is fully described in Bulletin No. 13 (p. 32), and that of the middle section, together with the Inangahua trough, will be discussed in Bulletin No. 18, now in preparation.

Viewed from Mount Buckland the Paparoa Range shows a congeries of bare jagged peaks and spurs, deeply dissected by the Ohikanui River and other streams. Former

* This is the spelling on page 55 of Haast's 1861 report, but elsewhere in this and also in other early reports the name is frequently spelt "Frederic."

glaciation on a moderate scale is indicated by cirques at the heads of various streams, by the deep, U-shaped valley of the Ohikanui, by accumulations of fluvio-glacial gravels at various points, and by the presence of small rock-basins, for example that occupied by Townson Tarn.

A feature of the northern portion of the Papahaua-Paparoa earth-block is that west of the Mount William Range erosion has almost everywhere removed the softer beds overlying the coal-measure grits and sandstones, so that the surface now exposed roughly corresponds to a former horizontal plane of deposition—that is, it follows the present undulatory conformation of the coal-bearing beds, and is an elevated structural plain. East of the Mount William Range denudation has proceeded a step or two further, and the coal-measures having thus almost entirely disappeared, a pre-Tertiary land surface, which is not greatly modified by modern stream-action, is consequently exposed over considerable areas. South of the Buller the once-existing coal-measures have been wholly removed from the higher portions of the Paparoa Range, and the old land thus exposed has been, as mentioned above, deeply dissected, partly by ice, but mainly by water.

Former Peneplanation.

In recent years various writers have regarded the highlands of Nelson, Westland, and Canterbury as forming portions of one or more elevated and dissected peneplains.* No very definite statements as to the date of peneplanation have yet been made. Morgan has suggested an early Miocene age† for the North Westland or Wainihinihi peneplain, but consideration of the facts now known indicates that peneplanation, if so widespread as supposed, existed in pre-Tertiary times. The chief reasons for this belief are the presence of Eocene outliers in various parts of Nelson, and the comparatively short interval between the Eocene and the Miocene, too brief to permit of base-levelling by erosive agencies. In the Westport district, so far as can be perceived, the Eocene coal-measures were deposited on a sinking old land that had previously been sufficiently levelled to be termed a peneplain. The depressed area, or a portion of it, was then considerably elevated, after which came the wide-spread Miocene depression. Since the Miocene, the land has been irregularly uplifted as explained elsewhere (pages 60, 62), and extensive denudation of the relatively soft Tertiary rocks has given rise to the present land-surface, which, as already stated, in many places bears a close relation to that existing immediately prior to the Eocene. Thus the Westport highlands, and with them probably the greater part of central and western Nelson, furnish an excellent example of what has been termed a fossil peneplain. The same feature is also observable in the Charleston district‡ and elsewhere in the lowland country. (See a later page.)

Coastal Region.

What may be called the coastal region consists of the extreme northern part of the Papahaua sub-block, together with the strip of land, widening from north to south, that lies west of the Lower Buller fault. North of the Mokihinui River the coastal region is a hilly bush-clad area in which the predominating rocks exposed are Miocene claystones and limestones. The ridges in general attain a height of 1,200 ft.

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* J. W. Gregory, "The Geography of New Zealand" (by P. Marshall), 1905, p. 9 ; J. M. Bell and C. Fraser, Bull. No. 1, 1906, pp. 24, 26–27 ; P. G. Morgan, Bull. No. 6, 1908, pp. 42–43 ; R. Speight and others (L. Cockayne, R. M. Laing), "The Mount Arrowsmith District," Trans. vol. xliii, 1911, pp. 319–21 ; J. Henderson, "On the Genesis of the Surface Forms and Present Drainage-systems of West Nelson," Trans., vol. xliii, 1911, pp. 309–11.

† N.Z.G.S. Bull. No. 6, 1908, pp. 35, 42.

‡ J. A. Bartrum : "The Geological History of the Westport–Charleston High-level Terraces." Trans., vol. xlvi, 1914, pp. 256, 258 (footnote), 261, &c.

to 1,600 ft., but trig. station J on the northern boundary has a height of 1,846 ft. Attention may be called to a decided ridge near the coast, which, however, is intersected by the Six-mile and Three-mile streams. This ridge is a continuation of Radcliffe Ridge, a similar feature seen south of the Mokihinui. The whole district is well dissected by the various streams that traverse it and have cut their beds down almost to grade for considerable portions of their courses.

Between the Mokihinui and Ngakawau rivers is an extension of the hilly country seen to the northward, which is not sufficiently high to be included in the mountainous part of the Paparoa-Papahaua earth-block. The most elevated points are trig. station AM (1,748 ft.) on Radcliffe Ridge, which runs parallel to the coast, and trig. station AN (1,728 ft.), which overlooks the gorge of the Ngakawau River at its deepest point. Though, on the whole, no more elevated than the district north of the Mokihinui, the area to the south has undergone considerably more denudation, so that Miocene rocks have disappeared, except on the western side of Radcliffe Ridge. The present surface elsewhere consists mainly of Eocene coal-measures and follows their structure to a notable extent. Chasm Creek, however, has cut a gorge through the coal rocks into underlying granite and gneiss, which also are exposed at several points in the watershed of Charming Creek.

The belt of country seaward of the Lower Buller fault begins as an extremely narrow coastal plain two miles north of the Mokihinui River. South of Granity it gradually widens, and at Cape Foulwind has an extreme width of eight miles. Structurally this coastal belt is of a complex character. The comparatively youthful coastal plain that fronts the sea from Gentle Annie Point to near Cape Foulwind is backed by high terraces south of Fairdown. These, south of the Little Totara River, become merged in an area of somewhat irregular relief with numerous exposures of Miocene claystone and limestone. Gravels, however, occur on almost all the ridgetops between the various streams, and in the watershed of the Nile are some gravel-covered pakihis at elevations corresponding to those of the high-level terraces seen to the northward.

From the dips exhibited by the Miocene rocks it may be inferred that west of the Lower Buller fault is an earth-block, tilted to the east, and bounded a few miles to seaward by a second fault approximately parallel to the former. Confirmation of this latter contention is given by the data obtained from a severe earthquake that occurred in February, 1913.* This had its origin south-west of Cape Foulwind, whilst a previous shock in 1912 had an origin to the north-north-east of the cape.† The supposed earth-block, which may be called the Westport block, probably closely corresponds to the Paparoa-Papahaua block, except that it lies some thousands of feet lower, and is largely covered by the sea.

The amount of dissection undergone by the coastal region varies with its elevation. North of the Ngakawau and again south of the Little Totara the physiography may be described as mature, while elsewhere it assumes more youthful forms. At Cape Foulwind, near Charleston, and north of the Ngakawau River an ancient land-surface of granite and gneiss has been exposed over considerable areas.

Recent Coastal Plain.—From Gentle Annie Point to the Buller River the Recent coastal plain embraces much the greater part of the area seaward of the Kongahu or Lower Buller fault. With it may be included the river-flat into which the delta of the Buller River appears to merge two or three miles inland. From Birchfield southwards the Recent coastal plain has a considerable width, but west of the Buller River it

* P. G. Morgan, "Earthquake at Westport, New Zealand," Bull. of the Seismological Society of America, vol. iii, No. 3, September, 1913; G. Hogben, "Notes on some Recent Earthquakes in New Zealand," Trans., vol. xlvi, 1914, pp. 301 3

† Hogben, *op. cit.*

Tiroroa Reach, Buller Gorge, between Hawk's Crag and Batty Creek. Note Outcrop of Hawk's Crag Breccia, showing Dip, on Left of Road.

is confined by Pleistocene terraces to a comparatively narrow strip, which, however, west of Bradshaw's is decidedly widened if a low terrace there seen can be considered Recent in age. As explained in Chapter V, there is difficulty in defining the boundaries of the Recent coastal plain, but it may be considered as passing inland of the somewhat elevated ridge near Cape Foulwind (which for some time must have formed an island) and again reaching the coast at Tauranga Bay. Hence to the Waitakere River near Charleston is a moderately wide but not well defined belt covered mainly by Recent sands, which for some distance south of Tauranga Bay form fixed sand-dunes, or ridges originally forested, and now in part cleared. These reach a height of fully 90 ft.

Part of the surface of the Recent coastal plain consists of open pakihi with a shallow peaty soil, but is hardly swamp in the ordinary sense of the word, for it is comparatively dry in fine weather, and even after heavy rainfall is crossable on foot, there being sufficient fall to carry away such water as is not absorbed by the peat. The subsoil usually consists of a foot or two of clayey silt, beneath which is compact gravel, with the uppermost layer in many places well cemented by oxide of iron. Towards the shore there are usually strips of typical swamp representing infilled lagoons, but these are bordered by a continuous sandy belt on which forest flourishes. Along the coast and in places inland are low dunes and well-defined beach-sand ridges. The deltaic areas near the mouths of the main stream, and the river-flats into which one or two of these merge—for example, the "Orowaiti flats" inland from Westport—have a fairly deep sandy or silty soil of moderately good to fertile character, and therefore have largely been brought under cultivation during the past fifty years.

Older Terraces bordering the Recent Coastal Plain.—As already mentioned, some comparatively low terraces have been included in the Recent coastal plain. Inland of these the gently rising surface of the coastal belt is broken by one or two steps, which, except where modified by the Buller and other streams, are not at all pronounced. These terraces, found chiefly between Westport and the Little Totara River, and to a smaller extent near Fairdown, have tops ranging from 100 ft. to nearly 250 ft. above sea-level. They flank an extremely prominent series of terraces, which in one step rise 250 ft. or more, so that the tops are roughly 500 ft. in height on their outer margins, and near the mountains may be fully 600 ft. Only one or two quite unimportant steps break the even surface of the high-level terrace-tops. All the terraces, it may be observed, have a gentle seaward slope, and the edges are usually parallel to the coast, except where they have been modified by the Buller or the minor streams that in general intersect them approximately at right angles. The high-level terraces are well developed to the east of Westport, where they are known by the names of Rochfort Terrace, Giles Terrace, German Terrace, Caledonian Terrace, &c. These really form one terrace, broken by the valleys of the Orowaiti and its various branches. West of the Buller, at practically the same level as the Orowaiti terraces, is Caroline Terrace, which, though interrupted to some extent by intersecting streams, may be regarded as reaching the Little Totara River. In the vicinity of Charleston the remains of various terraces, the most prominent being near the 500 ft. contour, are visible. Traces of others at still higher levels are also observable.

The terraces of the coastal region, with the exception of those south of the Little Totara River and inland of a limestone escarpment, all show a wave-cut margin facing the coast, and apparently the surfaces even of the highest have been determined mainly by the sea, though work performed by the Buller and other streams has complicated matters. Thus stream-gravels are found spread over the surface, whilst near the mountains pluvial deposits, talus, and some probable morainic material occur as surface accumulations. The writers have therefore to rely mainly upon McKay's evidence for the statement that in some places at least marine deposits occur beneath the stream-gravels covering the highest terraces, as, for example, east of Addison's. The lower terraces, composed of shingly gravel and sands, are obviously raised beaches. They contain black-sand leads, which have been extensively worked for gold (see Chapters II and VI).

The older terraces, except over small areas near Charleston, in which the bed-rock is gneiss, are everywhere built on a foundation of eroded Miocene strata, as is well seen in the deeply-cut valleys of the Totara and other streams. Near or at the top of the gravels that form the principal material of the terraces there is generally a layer cemented by oxide of iron, or in the absence of this a layer of clay, above which comes a thin covering of peaty soil. This, as a rule, is even more infertile than the similar soil of the poorer parts of the Recent coastal plain. Thus the terrace-tops form typical pakihi, and only on portions of the steep faces is any forest growth to be found.

Further remarks upon the terraces of the coastal region will be found in Chapter V. J. A. Bartrum has lately written a full account of the high-level terraces,* and to this the reader may be referred for further information, more especially concerning the mode in which the terraces have been formed and the somewhat involved post-Miocene history that they indicate.

Hilly Areas of Coastal Region west of Lower Buller Fault.—At Cape Foulwind is a small isolated ridge of gneissic granite on which repose Miocene claystone and limestone with a general easterly dip. Southward of the Little Totara River is a hilly district where the ancient terraces have been largely destroyed by the lateral erosion of the various streams. The rocks exposed are Miocene claystone and limestone, in most places capped by Quaternary gravel, of which the geological map shows a more continuous sheet than actually exists.

A limestone escarpment of the cuesta type, facing the sea, begins near the Waitakere (Nile) River, and extends southward to the boundary of the subdivision. Inland of the cuesta are wide flat-topped ridges of Miocene claystone, gravel-capped, and separated by the various branches of the Waitakere. Seaward is the gneissic surface of the fossil peneplain previously mentioned, partly hidden by Miocene coal-measures and Pleistocene gravels or sands.

Inangahua Gräben.

The Inangahua *gräben*, as developed within the subdivision, is formed by the tilted and relatively downfaulted eastern portion of the Paparoa-Papahaua earth-block. The Glasgow fault, beyond which rise the Brunner and Glasgow ranges, is its eastern boundary, but the western limit is somewhat indefinite, or, rather, there is difficulty in defining it. Since, however, the greater part of the *gräben* is outside the Buller-Mokihinui Subdivision, its full description will be left to the Reefton bulletin. The portion within the subdivision consists of the lower valleys of Pensini and New creeks, together with the flat at the great bend of the Buller River below the Lyell bridge. Southward the *gräben* continues through the Inangahua Survey District, and ultimately includes much of the Grey Valley.† Northward it appears to end near the junction of New and Roger creeks, where a fault striking north-easterly meets the Glasgow fault. A depressed area, however, the downtilted margin of the Paparoa-Papahaua block, still continues far to the northward, but various streams have cut their valleys across it, thus giving rise to transverse ridges, and the trough appearance is almost destroyed.

* "The Geological History of the Westport–Charleston High-level Terraces." Trans., vol. xlvi, 1914, pp. 255–62.

† N.Z.G.S. Bull. No. 13, 1911, p. 34.

River-flats and Inland Terraces.

The river-flats of the Recent coastal plain, such as those formed by the Buller, have already been mentioned. Of the flats not connected with the Recent coastal plain the largest is that at Seddonville, most of which has been cleared and grassed. There is a smaller flat lower down the river at St. Helens, separated from the other by a short gorge cut in hard sandstone or grit, and from the coastal plain by a longer gorge excavated in gneiss. The flats are due to the Mokihinui River having widened its valley in a downwarped area of soft Miocene and Eocene rocks, the position of which has been determined mainly by the eastward tilt of the Papahaua earth-block. The separating bar of hard rock above St. Helens owes its presence to a minor structural feature; but, if the river had worked somewhat more to the northward, a gorge would not have been formed at this point. Reference to the maps will make the matter clear.

At Corbyvale, in the extreme north-east of the subdivision, is a gravel flat with an area of five or six hundred acres. It has been formed by the accumulation of fan and flood-plain gravel in a stream-modified portion of the trough made by the tilting of the Papahaua earth-block against the Glasgow block, and therefore has essentially the same origin as the Seddonville flat. Of almost exactly similar genesis is a small flat to the south-west of Corbyvale in the upper valley of Six-mile Creek.

In the upper Ngakawau and Mackley watersheds are various small stream-flats flanked by flat-topped terraces of some size. The latter in respect of origin may be compared to the terraces inland of the limestone escarpment near Charleston.* The gravels that cover the flats and cap the terraces being as a rule thin, and having unsurveyed boundaries, are not indicated by the geological maps, which show merely the bed-rock—in this case soft Eocene mudstone.

The Blackburn pakihi, near the head of the stream of the same name, is peculiar in that it is quite flat to the eye, with the exception of three isolated hills of Eocene mudstone, and yet is practically devoid of surface gravel. It is part of the structural trough already mentioned, and its flatness is the result of work done by the Blackburn Stream and its branches on the comparatively soft mudstone that underlies the pakihi everywhere except at its northern or outlet end.

In the south-eastern part of Orikaka Survey District the Buller River and its tributaries, New and Pensini creeks, have formed a series of terraces and small flood-plains in the depression (Inangahua *gräben*) caused by the eastward tilt of the Papahaua block.

From its mouth to within a few miles of its source the Ohikanui River is bordered almost continuously by alluvial deposits. In the lower part of the valley narrow flood-plains are somewhat prominent, and may at a future date be found worth clearing and grassing. The soil, however, being formed mainly of sand derived from granitic rocks, is poor. The terraces that bound the flats or approach the river-banks, are of heterogeneous character, being composed of fluvio-glacial gravels, the fans of minor streams, pluvial deposits, and talus.

In the Blackwater Valley are several small areas of stream-flat and terrace, the largest of which is from one to two miles above the mouth of the stream. It has a poor soil, and is worth very little from an agricultural point of view.

Rivers.

The principal streams traversing the subdivision are the Mokihinui and the Buller or Kawatiri, both of which, however, have much the greater part of their

* See J. A. Bartrum, *op. cit.*, p. 260.

courses outside the area now being described. Smaller streams, with their watersheds wholly or mainly within the subdivision, are the Ngakawau, Waimangaroa, Totara, and Waitakere or Nile. There are many peculiarities in connection with the stream-courses, most of which, as will be seen from the following pages, are explained by the remarkable earth-movements that have taken place since Miocene times.

The Mokihinui River has its sources in wild mountainous country to the east and north-east of the subdivision. Its two chief branches, coming from opposite directions, join on a flat about six miles east of the subdivision boundary, and the united stream then flows westward in a series of calm reaches separated by rapids through a deep gorge, or in more technical language, canyon, cut in the Glasgow earth-block, whence it emerges into the Seddonville flat. Leaving this by the short, low gorge mentioned on page 53, it curves round the St. Helens flat, flows through a third gorge, and, traversing the narrow coastal plain, enters the sea. Only the last two miles of its course are tidal.

The gorges of the Mokihinui River require some comment. They were evidently formed during the elevation of the Glasgow and Paparoa-Papahaua blocks, and therefore it follows that the river is antecedent to the block-forming movements, or, at least, to those that took place after the land had emerged from the sea.

The Ngakawau River takes its rise on the western slope of the Glasgow Range, and after reaching the depressed inner margin of the Paparoa-Papahaua block flows northward or north-westward for several miles. In this part of its course it is joined at short intervals by various branches, some of which come from the Glasgow Range, one—the Blackburn—comes from the south, and one—St. Patrick Stream—has its sources comparatively near the sea, on the eastern slopes of Mounts Frederick and Augustus. After being joined by St. Andrew Stream it enters a most remarkable gorge, cut deep in gneissic rocks underlying Eocene coal-measures, from which it does not emerge until near the sea. The existence of this gorge may be considered proof that the river was antecedent to the main uplift and tilting of the Paparoa-Papahaua block, for it has actually cut through the summit of a domed elevation. A sketch by W. M. Cooper, which bears the suggestive title of "Hill cleft in twain," has been reproduced on Plate IX. (See also section on line AB, Ngakawau and Mokihinui survey districts, opposite page 76.)

While flowing through its gorge the Ngakawau is joined by Charming and Mangatini creeks. Between the headwaters of the latter stream, which rises near Mount Augustus, and those of St. Patrick Stream there is no well-defined boundary. As it emerges from the gorge the Ngakawau is joined by Mine Creek, which has its source between the heads of Mangatini and Granity creeks.

Attention may be called to the striking contrast between the Ngakawau, as seen in its gorge, and some of its tributaries, which flow as consequent streams down structural slopes of hard coal-measure grits, wherein they have cut gorges of moderate depth only. How far the latter streams represent the drainage existing prior to the erosion of the soft Kaiata mudstone that once overlay the grits is doubtful.

The Waimangaroa River, though a smaller stream than the Ngakawau, exhibits almost the same features. From its source near Mount Frederick it flows eastward for some miles parallel to the dip of the coal-measures, and therefore in this part of its course exhibits the features of a consequent stream. On reaching the foot of the Mount William Range it is diverted to the southward through the structural valley associated with the Mount William fault. At Kiwi Compressor the stream bends to the west, and enters a gorge that rapidly increases in depth until opposite Denniston it is nearly 2,000 ft. deep (see section on line CD, Kawatiri and Ngakawau survey districts and Plate X). Thus the lower course of the Waimangaroa River is evidently

PLATE IX.

"HILL CLEFT IN TWAIN BY THE RIVER NGAKAWAU." FROM A SKETCH BY W. M. COOPER.

[*To face page 54.*

antecedent to the main portion of the uplift of the Papahaua sub-block. After emerging from the gorge it flows over the coastal plain, and finally gives rise to a long narrow lagoon bordering the sea-coast.

The Buller River, the largest stream on the west coast of the South Island, enters the subdivision a mile or two below the old mining township of Lyell. It is here emerging from the Lyell Gorge, which is cut obliquely through the Glasgow-Brunner earth-block. Making a remarkable horse-shoe bend, partly conditioned by the Glasgow and other faults, it flows southward for a few miles in the Inangahua Survey District. After being augumented by the Inangahua River, it turns to the west and enters the well-known Lower Buller Gorge, cut through the Paparoa-Papahaua Range. A tributary of some consequence is the Mackley or Orikaka River, which flowing from the north joins the main stream two miles above Berlin's, where it re-enters the subdivision. In its further course through the gorge the Buller is joined by the Blackwater, Ohikanui, and various smaller streams. A few miles from Westport it emerges on the coastal plain, over which it flows with a northerly course to the sea. At its mouth is a delta of very moderate size for so important a stream.

From points near Westport somewhat vague indications of a wide and mature valley-floor may be seen high above the entrance to the Buller Gorge. The natural inference is that the supposed valley was formed by the ancient Buller at a time when the Paparoa Range stood much lower than at present, but the view obtained is imperfect, and the suggested interpretation of the physiography doubtful. Observations from different points of view, and perhaps a contoured map, are necessary before a definite conclusion can be reached.

Though a very large river, the Buller is tidal for little more than three miles from its mouth. Above the tide-limits it exhibits a series of calm reaches separated by rapids, and on the average has a grade of between 6 ft. and 7 ft. per mile. In the early days numerous gold-seekers ascended the river in canoes, and for a few years considerable traffic was borne by barges, which on their upward journey were drawn by horses past the rapids. The calm reaches in the Buller Gorge, as shown by a few soundings made in April, 1913, when the river was very low, have maximum depths of from 20 ft. to 40 ft., the deepest pool, found under Hawk's Crag, being 40 ft. 5 in. deep. During ordinary floods such as occur annually the Buller rises 20 ft. to 25 ft. in the gorge. Occasional floods exceed 33 ft., and the greatest known is reported to have covered the trusses of the Ohikanui Bridge, a rise of about 45 ft. above ordinary river-level at this point. The area of the Buller watershed has been estimated at 2,341 square miles, and its discharge at 990,897 cubic feet per minute, equal to 16,515 cubic feet per second.*

From what has been said on former pages with respect to the gorges of the Mokihinui, Ngakawau, and Waimangaroa rivers the reader will anticipate the statement that the Buller River is antecedent to the formation of the Paparoa, Brunner, and Glasgow ranges. The Lyell and Lower Buller canyons are therefore portions of the river-course that are probably just as ancient as any other part of the present Buller—for example, its headwaters. There is then no evidence to show that the Upper Buller once flowed down the Inangahua Valley to join the Grey River, but was captured by a small stream which had cut through the Paparoa Range, as supposed by Marshall.† Doubtless at one period a number of streams flowed westward from the Southern Alps to the sea, but during the formation of the block mountains and *gräben* of western Nelson most of these were partly or wholly diverted from their proper courses. The Buller, however, succeeded in maintaining its ancient direction

* "Handbook of New Zealand," 1886 (Hector), p. 64.
† "Geography of New Zealand," 1905, pp. 140–42.

with comparatively slight modifications. With it may be compared the Manawatu River, which is antecedent to the Ruahine-Tararua Range,* through which it has carved a deep canyon, corresponding in its main features to the Lower Buller Gorge.

The hypothetical Moutere River, supposed by Hector† and McKay‡ to have flowed in early Pliocene times from Blind Bay to Ross, or in the reverse direction, can never have existed if the Lower Buller is as ancient a stream as here predicated. This matter will be further discussed in the Reefton Bulletin (No. 18).

In writing the preceding pages the authors have tacitly made various assumptions which may or may not be correct. Thus it is supposed that the Southern Alps and their northern continuation, the Spencer and St. Arnaud ranges, were in existence during the Miocene, and that uplift began at the close of the Miocene in such a way that there was a consequent slope to the westward. Subsequently differential elevation, accompanied by strong faulting, gave rise to a number of earth-blocks in western Nelson. It may be that the formation of some of these blocks began in Miocene or earlier times. If so, the physiography of the Westport district becomes exceedingly complex; but the leading statements here made—namely, that differential earth-movements have determined the main physiographic features, and that the streams flowing through the mountain-ranges are antecedent to the latter—will still hold good.

The Totara River and various other smaller streams rise on the western slopes of the Paparoa Range in valleys slightly modified by glacial action, and after flowing through the coastal region enter a long narrow lagoon bordering the coast.

The Nile or Waitakere River, which reaches the sea near Charleston, is similar in most respects to the Totara, but is a considerably larger stream, and does not form a lagoon at its mouth, the conditions being unfavourable. The northward trend of its various branches is noteworthy. Before the emergence of the coastal region from the sea during the Pleistocene, these branches were separate streams, and the Waitakere, like the Totara, may thus be considered an engrafted river. Another noteworthy feature is the gorge that the main stream in its lower course has cut through Miocene limestone since the Pleistocene uplift. Near its mouth it has begun to incise the gneiss of the fossil peneplain mentioned on page 49.

Drainage-areas.—As measured by planimeter the drainage-areas of the main streams within the subdivision are as follows: Ngakawau, 40·1 square miles; Waimangaroa, 21·9 square miles; Ohikanui (tributary of Buller), 53·7 square miles; Blackwater (tributary of Buller), 34·5 square miles; Totara and Little Totara, together, 38·8 square miles; Waitakere,, 32·5 square miles (only that portion of watershed in subdivision measured).

Waterfalls.

Though there are no large waterfalls in the Buller-Mokihinui Subdivision the smaller streams, as might be expected in a region of such marked relief, exhibit many steep cascades and falls of considerable height, especially towards their heads. A small tributary of the Waitakere River has a drop of possibly 700 ft. or more, but this is in the Brighton Survey District, outside the subdivision. There is a very fine waterfall, with a drop of over 150 ft. on the Mangatini Creek at its junction with the Ngakawau. Throughout the area covered by coal-measures in the Papahaua sub-block small waterfalls are abundant. Some of these owe their existence to the cutting-back of a soft shaly

* H. Hill: "Notes on the Geology of the country between Dannevirke and Wainui, Hawke's Bay." Trans., vol. 26, 1894, p. 393, and Eighth Ann. Rep. N.Z.G.S., C.-2, 1914, pp. 132, 165.

† "Abstract Report on the Progress of the Geological Survey of New Zealand during 1866–67," 1867, p. 13.

‡ "Geological Explorations of the Northern Part of Westland," Mines Report, C.-3, 1893, p. 174. See also N.Z.G.S. Bull. No. 6, 1908, p. 115, &c.

stratum occurring under hard grit, whilst others are directly connected with minor faults which have caused a drop in the stream-bed.

Springs and Underground Watercourses.

Small springs depositing oxide of iron are abundant in many places. They may issue from gravel, Miocene claystone, or rocks belonging to the coal-measures. In Charming Creek, during a spell of dry weather when the stream was extremely low, numerous tiny springs smelling of sulphuretted hydrogen and forming minute deposits of sulphur were observed issuing from the dark mudstone of the coal-measures.

On the beach bordering the coastal plain numerous seepages of nearly fresh water may be seen when the tide is out. They are obviously due to percolation of surface water through the sand and shingle belt near the shore-line.

In places where limestone appears on the surface small streams disappear or partly disappear until the boundary of the limestone area is reached. The most notable example of this is the Six-mile Creek, about two miles west of Corbyvale.

Lakes and Ponds.

There are no sheets of water worthy of the name of "lake" in the Westport district. Lake Boyle, east of Mount Glasgow, and Townson Tarn, near Mount Buckland, are mountain tarns occupying ice-carved hollows. Lake Rochfort, on the western slope of the mountain with the same name, has been much enlarged by dams, and indeed may be wholly of artificial origin.

Near Westport, Addison's, and elsewhere the pakihis are dotted with many artificial ponds or "dams" of various sizes, all, except two reservoirs in connection with the Westport waterworks, constructed for mining purposes. The positions of most of these are shown on the maps.

Lagoons.

Quite a number of lagoons occur on the outer margin of the coastal plain. In order from north to south are the small lagoon at the mouth of the Mokihinui River; the series of long, extremely narrow lagoons entered by Jones Creek, Granity Creek, the Waimangaroa River, and other streams; the Orowaiti Lagoon; the Westport or Bradshaw Creek – Buller Lagoon, and the Totara Lagoon. These lagoons are similar in all respects to those of North Westland described in former bulletins.* The southern part of the Granity Creek Lagoon during the past fifty years has decreased in width and depth, presumably owing to material deposited by the inflowing streams, and in places has become a narrow belt of swamp. Similar strips of swamp between the old beaches west of Birchfield and elsewhere are evidently of analogous origin.

Shore-line.

From the southern boundary of the subdivision to the mouth of the Waitakere or Nile River, bold cliffs of gneiss front the sea, except at the two tiny bays near Charleston, one of which, Constant Bay, was formerly used as a port for small vessels. From Rahui, just north of the Waitakere, to Tauranga Bay, a distance of over eight miles, is the Nine-mile Beach, backed in most places by sandhills of varying height. At two to five miles north of Rahui, however, coastal dunes are absent, and only a narrow low strip of land separates the beach from the Totara Lagoon. Gneissic granite forms the south headland of Tauranga Bay and the high cliffs with their outlying islets and rocks northward to Cape Foulwind. Off the cape are three granite stacks—The

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* See N.Z.G.S. bulletins Nos. 1, 6, and 13.

Steeples—and a number of low rocks, mostly awash at high tide. These islets indicate the former extension of the shore in this locality at least two miles to the seaward of its present position.

From Cape Foulwind, where the coast bends to the east, vertical cliffs of Miocene claystone and sandstone, unconformably capped by a few feet of younger rocks, face the sea for nearly two miles. At their foot is a sandy or shingly beach, which, interrupted only by the mouths of the various rivers, continues along the margin of the coastal plain, and in most places has a background of low sand-dunes. As shown by the map of Steeples and Kawatiri survey districts, at the mouth of the Buller is a decided delta, the outgrowth of which is aided by the long moles constructed by the Westport Harbour Board. East of the Orowaiti Lagoon, perhaps as a result of the harbour-works, the sea during recent years has eaten away a strip of the coast, here curving to the north-east: elsewhere a slight outward growth of the land has probably taken place. For many miles to the northward the beach is of a uniform character, but at Granity a few isolated stacks known as the Torea Rocks give some variety. At Gentle Annie Point, two miles north of the Mokihinui, the sea beats against light-coloured cliffs of calcareous rocks. For some miles to the north cliffs of fault-crushed, brecciated granite bound the shore, but at Kongahu Point, the extreme northern point of the subdivision, calcareous rocks again appear at sea-level, and form a line of high cliffs for some miles to the northward, as mentioned by Webb.* A few outlying rocks and islets between Gentle Annie and Kongahu points show that during Recent times the sea has encroached upon the land.

Von Haast mentions that he observed a sunken forest on the coast-line east of Cape Foulwind, and suggests earthquakes as the cause of the subsidence.† These may have taken place during the years 1826 and 1827, when severe shocks were felt by sealers on the west coast of Otago.‡ Since 1860, all traces of the sunken forest seem to have been removed through decay of the trees and the action of the sea.

Outline of Geology.

Introductory.

The geological formations in the Westport district are easily divided into two sets separated by a striking unconformity. The one, of great antiquity, consists mainly of highly folded greywacke, argillite, hornfels, schist, gneiss, and intrusive acid igneous rocks such as granite and quartz-porphyry. In pre-Tertiary times these rocks, it would seem, were base-levelled, and upon the peneplain so produced was deposited the second set of strata, consisting of a succession of breccias, conglomerates, grits, sandstones, mudstones, and limestone, in places unconformably capped by Quaternary sands and gravels.

Sequence and General Structure of the Several Formations.

In the study of the older set of rocks it was found that in places a complex of granite, gneiss, and schistose rocks of apparently sedimentary origin was exposed. Some evidence was also obtained showing that the gneiss and schist unconformably underlay argillites and greywackes believed to be of Ordovician age. Hence the

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* N.Z.G.S. Bull. No. 11, 1910, p. 3.

† "Topographical and Geological Exploration of the Western Districts of the Nelson Province, New Zealand," 1861, pp. 111–12. Heaphy, however, who in 1846 observed standing and uprooted trees below high-water mark near Cape Foulwind, ascribes the phenomenon to erosion by the sea, and does not suggest subsidence.

‡ Rev. Richard Taylor: "New Zealand and its Inhabitants," 1855, p. 235; quoted by R. McNab in "Murihiku and the Southern Islands," 1907, p. 262. See also Lyell's "Principles of Geology," 12th edition, 1875, vol. ii, p. 82.

TABLE OF GEOLOGICAL FORMATIONS.

McKay (1895).	Park (Geology of N.Z., 1910).	Marshall (N.Z. and Adjacent Islands, 1912.)	Bull. No. 3 (1907).	Bull. No. 11 (1910).	Bull. No. 13 (1911).	This Bulletin.	Age.
Recent— Glacier and river alluvia; littoral.	Recent.	Recent.	Newer Débris.	Newer Débris.	Recent Deposits— Fluviatile and marine gravels and sands.	Recent Deposits— Fluviatile and marine gravels and sands, talus, &c.	Recent.
Pleistocene — High-level old river-channels and terraces.	Pleistocene.	Pleistocene.	Older Débris.	Older Débris.	Pleistocene Deposits— Morainic fluvio-glacial, fluviatile, and marine gravels, &c.	Pleistocene Beds— Morainic fluvio-glacial, fluviatile, fluvio-marine and marine gravels, marine sandstone, &c.	Pleistocene.
Pleistocene and Younger Pliocene.							
Older Pliocene and Upper Miocene.	Wanganui System (part of).	Wanganui System.			Pliocene Beds— Sandstones, lignites, and gravels.	Not represented.	Pliocene.
Lower Miocene.	[Wanganui System.*]						
Cretaceo-Tertiary and Cretaceous— Upper.	Karamea System. Oamaru Series.	Oamaru System.	Oamaru System. (1.) Blue and yellow clays. (2.) Limestones. (3.) (a.) Sandstones, shales, coal-seams, and conglomerates. (b.) Quartzose conglomerates.	Kongahu Series. Upper: Sandstones and conglomerates, with small lignite seams. Lower: Sandstones, breccias, grits, and limestones.	Greymouth Series. "Blue Bottom" formation. Cobden limestone, Port Elizabeth beds. Omotumotu beds.	Oamaru Series. (3) Upper: Claystone and sandstone. (2) Middle: Limestone, claystone, and sandstone. (1) Lower: Sandstone, grit, shale, and conglomerate with brown coal and lignite.	Miocene.
Middle. Lower.	Karamea System. Waimangaroa Series.		—	—	Coal-measures. Kaiata mudstone. Island sandstone. Brunner beds. Paparoa beds.	Bituminous Coal-measures (Mawheranui Series). (3) Kaiata beds. (2) Brunner beds. (1) Hawk's Crag breccia and breccia-conglomerate.	Eocene.
[Te Anau Series (Devonian).]	[Te Anau Series (Devonian).]	[Baton River System (Silurian).]	Haupiri Series.	—	Not represented.	Not represented.	Uncertain Palæozoic.
Maitai Series (Carboniferous)	Hokonui System (?) (Part of). [Kakanui Series = Aorere Series.]	Aorere System.	Aorere Series— Argillites, greywackes, and quartzites (Ordovician). Crystalline schists and quartzites. } Highly metamorphic rocks. Crystalline complex carbonates. } Highly metamorphic rocks.	Aorere Series. —	Greenland Series. —	Aorere Series— Argillites, greywackes, hornfels, schists, &c. —	Siluro-Ordovician (in part older (?)).
Massive and Intrusive Granites.	[Igneous Rocks.]	[Igneous Rocks.]	Igneous Rocks. Ultra-basic. Basic and semi-basic. Acidic.	Igneous Rocks. Intermediate and basic. Acidic dykes. Main granitic intrusives.	[Basalt.] Basic dykes. Tuhua Formation.	Igneous Rocks. Basic dykes. Intermediate rocks. Acid dykes. Quartz-porphyry. Granite and gneiss.	Early Tertiary (in part only (?)). Post Ordovician and Pre-Tertiary.

* The Awatere Series, at the base of the Wanganui System as defined by Park, is probably equivalent to the Upper Oamaru of this bulletin.

[To face p. 58.

tentative conclusion was reached that the former rocks represented an extremely ancient series, the sedimentary portion of which was perhaps of pre-Cambrian age, whilst the gneiss represented a pre-Ordovician intrusion of granite. Later, Ordovician sedimentaries were deposited, and a second series of granitic intrusions took place. The attempt to apply these views, however, broke down, and all the ancient sedimentaries have been placed in a single series, whilst all the gneisses, granites, and other acid igneous rocks have similarly been grouped together.

According to McKay's classification, the ancient argillites, greywackes, and associated rocks belong to the Maitai Series of supposed Carboniferous age, but, for the reasons given on page 68, this view cannot be adopted by the writers, and the rocks in question have been placed in the Aorere Series, which is known to be, in part at least, of Ordovician age.

The Tertiary formations are represented by two main divisions, the Mawheranui or Waimangaroa Series, and the Oamaru Series. The former series begins with the Hawk's Crag breccia and the coal-bearing Brunner beds, which are terrestrial deposits, and ends with the Kaiata beds of marine origin. The basal rocks of the Oamaru Series are mainly terrestrial in origin, and contain seams of brown coal. Above the coal horizon are marine sandstone and mudstone followed by limestone, on which rest thick beds of bluish mudstone or sandstone.

Pleistocene and Recent deposits comprise high-level stream and marine gravels, ancient beach-sands, fluvio-glacial gravels, and the more modern river and marine deposits, together with talus and pluvial deposits at the foot of mountain-slopes.

The table facing page 58 shows the classification adopted in this bulletin, together with the classifications of various other authors. The present writers are responsible for some slight modifications necessary to enable the tabular form of presentation to be used.

Geological History.

The geological history of the Buller-Mokihinui Subdivision forms part of that of western Nelson, and until the whole region has been studied in detail satisfactory conclusions concerning the older formations cannot be reached. In the meantime the geological history of North Westland, as given in Bulletin No. 13 (Greymouth), if somewhat qualified, may be regarded as having a general application to the Westport district.

Nothing can here be added to the remarks already made concerning the possible pre-Ordovician schists and gneisses of the subdivision. In Aorere (Siluro-Ordovician) times western Nelson, Westland, and adjoining districts probably formed the foreshore of a continental area, but the position of this land relatively to the present west coast of the South Island is uncertain. The suggestion has been made that this ancient continent extended far to the west, and, persisting through the Palæozoic periods into the early Mesozoic, was in fact a portion of Gondwanaland.* This hypothesis, however, for the present must be regretfully dismissed.†

Of the many geological changes that doubtless occurred during late Palæozoic and Mesozoic times, no certain record remains, denudation having removed all sediments that may have been deposited during these periods. It is probable, however, that, some little time before the Triassic, granitic intrusions took place, and were accompanied by far-reaching changes. The existing sedimentary rocks were folded, mainly along north-west to south-east lines, and in places metamorphosed. Concomitantly, there was

* P. Lemoine: "Etudes Geologiques dans le Nord de Madagascar," 1906, pp. 464, 466. See also N.Z.G.S. Bull. No. 6, 1908, pp. 32–34.

† See E. A. Newell Arber: "On the Earlier Mesozoic Floras of New Zealand." Proc. Cambridge Phil. Soc., vol. xvii, pt. i, Feb. 1913, p. 123.

presumably notable elevation of the land, followed by extensive denudation. Whether or not during the Trias-Jura period, which is so strongly represented in many parts of New Zealand, there was deposition of sediment in western Nelson cannot be stated. Throughout the Cretaceous, however, denudation appears to have been prevalent, with the result that the surface of the greater part of Nelson, including the Westport district, was reduced to the condition of a peneplain.

About the end of the Cretaceous, or during the Early Eocene, some remarkable earth-movements in the nature of local elevation accompanied by violent faulting seem to have taken place within or near the district extending southward from Mount Rochfort towards Reefton and Greymouth. Over part of this area an enormous thickness of fault-smashed angular and semi-angular fragments of rock was distributed in the form of talus and pluvial deposits. For these deposits, which form the Hawk's Crag breccia, McKay suggests a glacial origin, but the genesis just stated seems much more probable. Either contemporaneously with the breccia or at a slightly later period the conglomerates of Mount Rochfort and other localities were formed. Depression of the land was now taking place, and in a shallow freshwater lake (or lakes) was deposited a series of grits, sandstones, and shales with layers of vegetable matter, later transformed into bituminous coal. Continued sinking of the land permitted the transgression of the sea, and thus resulted in the formation of a considerable thickness of marine strata, consisting largely of mudstone, with minor sandstone and limestone.

Between the Eocene and the Miocene, elevation, followed by considerable denudation of the bituminous coal-measures, took place, but during the Miocene (Oamaru period) the land again sank. Upon the sinking surface conglomerates, sandstones, and shales, with layers of vegetable matter now transformed into brown coal, were deposited. Once more the sea invaded the land, and that more widely than during the Eocene, so that marine sandstones, mudstones, and limestones of Miocene age correspondingly overlap the Eocene rocks.

During the Pliocene notable elevation occurred, but the movements were differential, so that some parts of the land hardly rose, whilst portions of tiited earth-blocks, separated by enormous meridional faults, were forced to great heights. The mountains for a time were sufficiently lofty to become the home of glaciers, which during the Pleistocene in places descended to the lowlands. A well-marked depression in the early or middle Pleistocene was followed by periods of minor elevation alternating with periods of rest or slight depression, the upward movements predominating, so that at the present day raised beaches are found several hundreds of feet above sea-level. Before the close of the Pleistocene the glaciers on the Paparoa and Glasgow ranges had entirely disappeared. Since then there has been slight further elevation of the land, the modern part of the coastal plain has formed, the sea-cliffs have been cut back, and considerable denudation of the more elevated portions of the subdivision has taken place.

VIEW OF WAIMANGAROA GORGE, LOOKING WESTWARD FROM THE NEIGHBOURHOOD OF DEEP CREEK.

VIEW LOOKING UP OHIKANUI RIVER VALLEY FROM A POINT NEAR JUNCTION OF STREAM WITH BULLER. PART OF BUCKLAND PEAKS IN RIGHT BACKGROUND.

SOUTHERN END OF RAHUI BEACH. THE ROCK OUTCROPS NEAR THE INN, AND ON THE BEACH ARE GNEISSIC GRANITE

CHAPTER IV.

FAULTS OF THE AREA.

Introduction.

The physiographic details given in the preceding chapter indicate that fault-fractures are remarkably prevalent in the Buller-Mokihinui Subdivision, and that the main physical features of the area have been determined by the associated earth-movements.* The major faults in many places determine geologic and topographic boundaries, whilst dislocations of smaller extent hinder the economic working of the bituminous-coal mines. On the bare uplands extending from Mount Rochfort to the Ngakawau River the faults are generally easily traced, but elsewhere, owing to the forest covering and the rugged topography, exact mapping is almost or quite impossible. The great faults, however, can be at least approximately mapped, and data obtained, which though imperfect, afford results of considerable interest and importance.

Age of Faults.

The two major faults of the subdivision involve Miocene rocks, and are therefore of post-Miocene age, but it is possible that fracture began in an earlier period. Various other faults traverse Miocene rocks, whilst the Eocene coal-measures have been dislocated by hundreds of faults, great and small, most of which are probably of post-Miocene age. Though this statement cannot be conclusively proved, yet the writers may assert with some confidence that the minor fractures are subsequent rather than antecedent to the major faults, which are, as just mentioned, in part at least, of post-Miocene date.

The Palæozoic rocks of the subdivision were undoubtedly severely affected by faulting in pre-Tertiary times, and one or two of these early faults have been detected, but, as a rule, data for determining pre-Tertiary faulting are lacking.

Faulted Blocks and Nature of Faulting.

The two great earth-blocks—the Paparoa-Papahaua and the Glasgow-Brunner—of the subdivision are described in the preceding chapter, where also mention of the Westport block and of the Mount William sub-block is made. An inspection of the maps will show the presence of numerous minor blocks, especially in the Seddonville district, where faults are more plentiful, or have been more completely mapped, than in other parts of the area.

Hector perceived the existence of faulted blocks in the Westport district, and discussed their mutual relations in the following terms: "Notwithstanding that these dislocations or faults are of great extent and magnitude, the vertical displacement in

* The reader should not omit to consult an interesting and important report by Alex. McKay, entitled "On the Geology of Marlborough and South-east Nelson," pt. ii, in Rep. G.S. during 1890–91, No. 21, 1892, pp. 1–28, where an excellent account of the major New Zealand faults and their influence upon topography is given.

some instances being as much as 1,200 ft., it is most probable that they are due rather to the local subsidence of portions of a formation that had been raised in mass than to an unequal exercise of the elevating force in the first instance. This consideration is one of primary importance in tracing the extension of these coalfields and discovering the occurrence of workable seams at low elevations, and from what I observed I am inclined to expect that under a formation of brown sandy shale and septaria clays which skirts the seaward base of Mount Rochfort, the same coal-seam may probably occur as that on the summit of the range."*

Although not disagreeing with Hector's last statement as quoted above, the writers have already made it clear that there was "an unequal exercise of the elevating-force." The various blocks were more or less tilted during uplift, whilst the Paparoa-Papahaua and Glasgow-Brunner blocks were elevated to a far greater extent than the Westport block. The view taken by the writers is that the energy consumed in producing uplift was, so to speak, economized or conserved, so that no important block was raised to a great height, and then almost immediately allowed to subside.† This statement, it may be well to say, does not apply to the minor blocks, most of which, no doubt, are due to normal faults accompanied by subsidence on the hanging-wall side.

Since it is considered that in the case of the major faults uplift on the eastern side rather than downthrow on the western side took place, it follows that the forces at work were tensional rather than compressional. The actual fault-planes, so far as observable, are either slightly inclined away from the upthrow side—that is, towards or under the relatively lower side of the fault—or are vertical. The major faults, therefore, cannot be called reversed faults, though they are essentially of that nature, and correspond closely to fractures on the steeper slopes of unsymmetrical anticlines. The effect of fracture is not easily dissociated from that of folding, and hence the estimates of throw presently to be given include a varying component due to folding. A similar difficulty arises with some of the smaller faults—for example, the Mangatini fault—in which part of the disturbance is due to a minor fold or "roll." There can be little doubt, moreover, that the presence of unyielding granite, or of indurated and highly-folded Palæozoic rocks beneath the Tertiary strata on the one hand has prevented the latter from being regularly folded, and on the other has increased the amount of faulting to which they have been subjected.

Detailed Description of Faults.

Lower Buller or Kongahu Fault.

In 1892 McKay, in an illuminating report, noted and mapped a great fracture along the western base of the Paparoa and Papahaua Mountains under the name of the Lower Buller fault.‡ Many years later Webb described a considerable fault which extends north-eastward from Kongahu Point.§ The survey of the Westport district has shown that this dislocation extends southward, and merges into the Lower Buller fault. The latter name certainly has priority, but the name of Kongahu fault, given in the field, found its way to the map prepared for publication, and is therefore retained in this bulletin as an alternative to that bestowed by McKay. A graphic description of the fault is given by McKay, who, however, underestimates its maximum throw and probably exaggerates its length. The writers may be here allowed to observe that the modifications of McKay's statements rendered necessary by later surveys do not sensibly

* "Abstract Report on the Progress of the Geological Survey of New Zealand during 1866–67," 1867, p. 11. See also p. 23 of report with same title and nearly same matter published in 1868 (Rep. G.S. No. 4).

† See also Chapter III, under the heading of "Rivers."

‡ "On the Geology of Marlborough and South-east Nelson," pt. ii, Rep. G.S. during 1890–91, No. 21, 1892, p. 22.

§ "The Geology of the Mount Radiant Subdivision," N.Z.G.S., Bull. No. 11, 1910, p 11 lessen the value of his work, which was founded on a series of reconnaissance surveys, and is of the greatest importance to students of New Zealand geology.

Near Kongahu Point the fault mapped by Webb is probably joined by a branch coming from the north-north-east, which determines its direction for many miles to the south. For some distance the fault follows the present coast-line, and then, as shown by the maps, passes a little inland. It is, however, actually distributed over a zone of some width, the outer margin of which is to seaward of the coast. South of Granity, as the coastal plain widens, it gradually leaves the shore-line, but preserves its relatively straight course as far as Waimangaroa. From Waimangaroa to near Addison's the fault repeatedly curves in strike, and is distributed into a number of components. The complexity of the structure on the western side of Mount Rochfort is increased by the presence of a great fold in the bituminous coal-measures, which to some extent takes the place of the fault. The map of Kawatiri Survey District and the cross-section GH, although far from being absolutely correct, give a fair idea of the probable nature of the fault between Waimangaroa and the Buller.

From Addison's to the southern boundary of the subdivision the fault appears to be of a more simple nature than to the northward, and trends with a fairly straight course a little west of south. The almost complete removal, owing to denudation, of the Eocene coal-measures from the slopes of the Paparoa Range probably much simplifies the structural details.

The throw of the Lower Buller or Kongahu fault increases, somewhat irregularly, from north to south. At Kongahu Point it is probably between 1,000 ft. and 2,000 ft.; at Granity it is over 3,000 ft.; whilst at Waimangaroa the displacement, including the difference of level caused by the associated monoclinal fold or curvature in the Eocene coal-measures, must be 5,000 ft. or more. South of the Buller the total displacement is probably 7,000 ft. or 8,000 ft., and this throw is maintained to the boundary of the subdivision. The reader may again be reminded that the movement connected with the fault was mainly elevation of the block to the eastward, and not subsidence of the block to the west, which, indeed, has also been elevated to some extent.

Glasgow Fault.

In its main features the Glasgow fault is strikingly similar to the Lower Buller fault. It has a meridional strike, with an easterly upthrow, rapidly increasing southward for the first few miles of its course until a displacement of not less than 6,000 ft. is attained.

The fault enters the subdivision at Corbyvale, in the north-east corner of the Mokihinui Survey District. Here it is a well-marked fracture, striking to the south-west, but apparently does not live far to the north-east, for it is not shown by Webb in his map of the Mount Radiant Subdivision. West of Mount Kilmarnock, owing to its becoming associated with a meridional fault-zone, it assumes a southerly course. The reader will note that the behaviour of the Lower Buller fault at Kongahu Point affords an exact parallel. After crossing the Mokihinui River, where its throw is already several thousand feet, the fault follows the western base of the Glasgow Range and preserves a slightly east-of-south course for many miles. Near the bridge over the Buller River south of Lyell it passes outside the eastern boundary of the subdivision. From this point it forms the eastern boundary of the Inangahua *gräben* or trough, and the western boundary of the Brunner Range, the structural continuation of the Glasgow block. Additional details concerning the Glasgow fault will be found in a forthcoming publication* which deals with the Inangahua and adjoining districts.

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* N.Z.G.S. Bull. No. 18: "The Geology and Mineral Resources of the Reefton Subdivision," by J. Henderson.

Mount William Fault.

Forming the western boundary of the Mount William Range is the Mount William fault, which was noted by Hector as a dislocation with a vertical displacement of 1,200 ft.,* and has also been mentioned by Cox,† R. B. Denniston,‡ and McKay.§ In its main features it resembles the Lower Buller fault, the strike being south-south-westerly, and the upthrow to the east.

The most northerly point where the fault has been distinctly observed is about a mile and a half north of trig. station AF, and less than a mile south-east of the Westport-Stockton Coal Company's new workings. West of AF the throw of the fault is probably over 400 ft., but at the saddle half a mile to the south has temporarily diminished to about 250 ft. At Wilson Saddle the throw is approximately 500 ft., at Cedar Creek Saddle 900 ft., and west of Mount William trig. station over 1,500 ft. In this locality the fracture assumes a more westerly strike, the change being evidently associated in some way with the greater elevation of Mount William. Resuming a more southerly direction the fault, with diminishing throw, continues down the valley of Cascade Creek, crosses a saddle, and, following Redmond Creek valley, reaches the Buller. It appears to traverse the Ohikaiti Valley obliquely, and, passing over a saddle into the Ohikanui watershed, perhaps ends as shown by the map of Ohika Survey District. The upper Ohikanui Valley, however, is in line with the fault, and to a slight extent may be determined by it.

Faults near Seddonville.

The Eocene coal-measures between Seddonville and the Ngakawau River are intersected by a large number of faults, some of which will again be mentioned in Chapter VI during the detailed description of coal-bearing areas. Several of these fractures are described by Hector‖ and McKay¶ in the old geological survey reports. In a general way the faults in this district may be said to follow two prevailing directions, one of which is north-north-east, parallel to the Kongahu or Lower Buller fault, and the other slightly south of east. In addition there are a few faults with a north-easterly strike.

Faults of Denniston-Millerton Uplands.

The chief faults traversing the open uplands between Mount Rochfort and the Ngakawau River are usually easily traced on the surface, owing to their giving rise to prominent cliffs, and also because the scanty soil and vegetation hide very little from the eye of the observer. Various faults are mentioned by Cox and Denniston in their reports published in 1877, but are not satisfactorily indicated either in the published maps or in a map with manuscript additions (probably made by Denniston) now in the possession of the Geological Survey.

The cliffs that mark nearly all the faults are not the original scarps, but renewals of them, due mainly to the removal of the comparatively soft Kaiata beds that once overlay the coal-measure grits and sandstones, and may therefore be called fault-line scarps.** The reader ought to note, however, that in many cases the reproduction of the original scarp is of a perfect character, so that the modern scarp is on the line

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* *Op. cit.* (1867), p. 11.

† "Report on Survey of Buller Coalfield." Rep. G.S., No. 9, 1877, p. 22.

‡ "Detailed Notes on the Buller Coalfield." Rep. G.S. No. 9, 1877, p. 133. Here Denniston speaks of the "Great East Fault."

§ "On the New Cardiff Coal Property, Mokihinui Coalfield." Rep. G.S. during 1890–91, No. 21, 1892, p. 78.

‖ "On the Mokihinui Coalfield," Rep. G.S. during 1886–87, No. 18, 1887, p. 157. See also accompanying map.

¶ "On the Mokihinui Coalfield," Rep. G.S. No. 18, pp. 162, 163, 166; "On the New Cardiff Coal Property, Mokihinui Coalfield," Rep G.S. during 1890–91, No. 21, 1892, map and sections opposite p. 80; "On the Mokihinui Coal Company's Property, Coal Creek, Mokihinui," same volume, pp. 90 *et seq.*

** See W. M. Davis: "Nomenclature of Surface Forms on Faulted Structures," Bull. Geol. Soc. of America, vol. xxiv, 1913, pp. 206–7, &c. The Westport fault-line scarps would be classed by Davis as "resequent."

of fracture, is exceedingly steep, and has a height about equal to the throw of the fault. This last feature may be expressed in another way by saying that the hard grits and sandstones of the coal-measures have been but little eroded, and owing to the ease with which weathered material once produced can be removed by storm-water from their barren surfaces, denudation has acted almost uniformly on both sides of the fault-scarps, since the re-exposure of the grits, &c.

The various dislocations of the Denniston-Millerton uplands, like those of the Seddonville district, with few exceptions fall into two sets, one composed of faults approximately parallel to the main fractures, the other of faults striking to the south of east. Almost all are normal faults, apparently produced by tensional strains. On the bare upland surfaces many may be observed to begin as small displacements, which increase to a maximum, and then gradually die away. Not infrequently more or less silicification has taken place along the fault-planes, so that white siliceous shells are frozen to the walls. In some instances, especially where the movement has not been great, these show prominent slickensides and grooves, which more often than not make a decided angle with the direction of dip, thus showing that the fault-movement had a horizontal component (heave) as well as a vertical one (throw).

Of the faults approximately parallel to the major fractures the most important are Kiwi and Webb faults. The former of these may be traced from a point near Kiwi Compressor for nearly three miles to the east of north. In the middle part of its course it is indicated by a very high cliff facing the Mount William fault-scarp, and if a closely adjoining parallel fracture be included has a total downthrow to the east of 250 ft. or more. Webb fault appears to begin a few hundred yards to the south-east of the northern end of Kiwi fault as mapped, and like it trends to the east of north. It has a length of over three miles, and finally dies away near Fly Creek. The downthrow is again easterly, and, as judged from the scarp near the point where upper St. Patrick Stream crosses the fault, reaches a maximum of over 100 ft.

There is a considerable fault on the west side of Cascade Creek which has its downthrow to the east-south-east, and in conjunction with the Mount William fault forms a trough containing a small area of coal-bearing rocks. Near the head of Cascade Creek there is also some downwarping of the strata, so that owing to this and to the bush that covers the surface in this locality definite data concerning the fault cannot easily be obtained. Cox speaks of two "slips" or "breaks" in the valley of "Todea" (*i.e.*—Cascade) Creek, and discusses them at some length.* One of these, the "second slip" or the "Creek Break" (see Cox's sections), corresponds to the fault just mentioned, but the existence of the other, called by Cox the "first slip" or "Cascade Break" is doubtful, the appearance of faulting being due mainly or entirely to the combined effects of warping and of denudation. This so-called "Cascade Break" extends as an escarpment or cliff south-westward towards Mount Rochfort, where it is of great height, though not nearly so high as stated by Denniston, who speaks of an "all but perpendicular face varying in height from 1,000 ft. to 2,000 ft."

Among the faults striking transversely to the major fault direction, the Millerton and Mangatini faults are the most prominent. Both are somewhat complicated by small monoclinal folds or "rolls" in the adjoining strata. The Millerton fault extends in a somewhat south-of-east direction from a point west of Millerton to A. J. Creek, a tributary of the Mangatini. It thus interrupts the whole width of the bituminous coal-measures in this neighbourhood. The throw is northerly, and, if judged from the steep slope that marks the fault, must be considerable, though not anywhere so great as Denniston's estimate of 200 ft.† This slope, however, cannot easily be made the

* "Report on Survey of Buller Coalfield." Rep. G.S. during 1874–76, No. 9, 1877, p. 109. Sections face p. 112. See also R. B. Denniston, "Detailed Notes on the Buller Coalfield," in same volume, pp. 132, 133, &c.

† *Op. cit.*, p. 137, where it is called fault No. 5. On p. 124 the same fault is mentioned as "fault No. 4."

basis for even a rough estimate of the displacement due to fracture, because the dip of the strata, in places intensified, increases the apparent throw. Near Millerton, indeed, the fault may have small throw, the preponderating factor being "roll" but displacement is evident and probably predominates where it crosses Mine and Mangatini creeks.

The Mangatini fault as shown on the maps extends from the upper part of Granity Creek for nearly three miles in a south-south-east direction. The western two-thirds of the fault is much more a "roll" or monoclinal fold than an actual fracture, as is clearly shown by the surface strata (See Fig. 1). Near Mangatini the fracturing consists of small reversed faults, with a southerly downthrow opposed to the roll, as shown by Fig. 1. In the eastern part of the Westport-Stockton Company's lease there is little or no appearance of roll in the strata; and a northerly downthrow of about 50 ft. is indicated by a cliff of that height. Near St. Patrick Stream the fault seems to die away.

The maps sufficiently illustrate most of the other faults observed in the district between the Ngakawau River and Mount Rochfort. Very interesting, though of no importance, is a series of small reversed faults seen a short distance east of the bridge over Mangatini Creek between the Westport-Stockton Company's B and C tunnels. These are shown by Fig. 2.

Area East of Mount William Range.

In the valley of the Blackburn, in the watershed of Pensini Creek, and in other parts of Orikaka Survey District are some considerable faults. Owing to the forest covering, the difficulties of access, and the unpromising nature of most of this country, these were not fully or accurately determined, and, as will be seen on inspection of the maps, are represented more or less ideally by straight lines.

Eastern Part of Ohika Survey District.

The faults mapped in the eastern part of Ohika Survey District, like those already discussed, for the most part fall into two groups, one striking north-north-east, the other east-south-east. To the former group belongs a strong fault or fault-zone which follows the Blackwater valley for the greater part of its length, and is indicated in several places by bands of crushed rock. Of the east-south-east faults that following Stable Creek valley on the north side of the Buller is mapped with considerable accuracy from the sudden changes of rock outcrop produced by it. This fault probably continues into the Berlin's reach. The long and straight reach (see Plates VIII and XII) of the Buller between Tiroroa and Hawk's Crag is probably connected with a considerable fault, of which direct evidence is seen at the eastern end. The fracture with north-north-west strike shown crossing the Buller east of Hawk's Crag is to some extent ideal, but topographical evidence favours it. Parallel faults are not improbably present, but the writers did not venture to show these on the map, though their existence has been assumed in the mapping of the boundary between Miocene and Eocene rocks. It is possible that north-north-east-striking faults follow the valleys of Payne (Slaty) and Newman creeks, which enter the Buller east of Stable Creek. If these could be proved, a connection between the directions of the faults and those of the streams in the Buller Gorge district would be strikingly apparent.

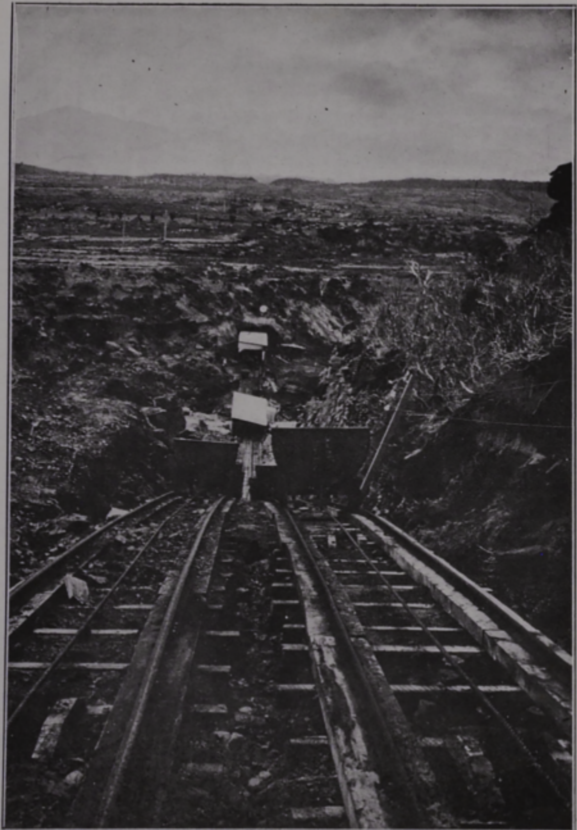
Hypothetical Seaward Fault.

The chief evidence for the existence of an active fault to the seaward of the present coast-line—namely, the easterly tilt of the coastal region rocks, and the testimony afforded by earthquakes—has already been stated (see Chapter III, p. 50).

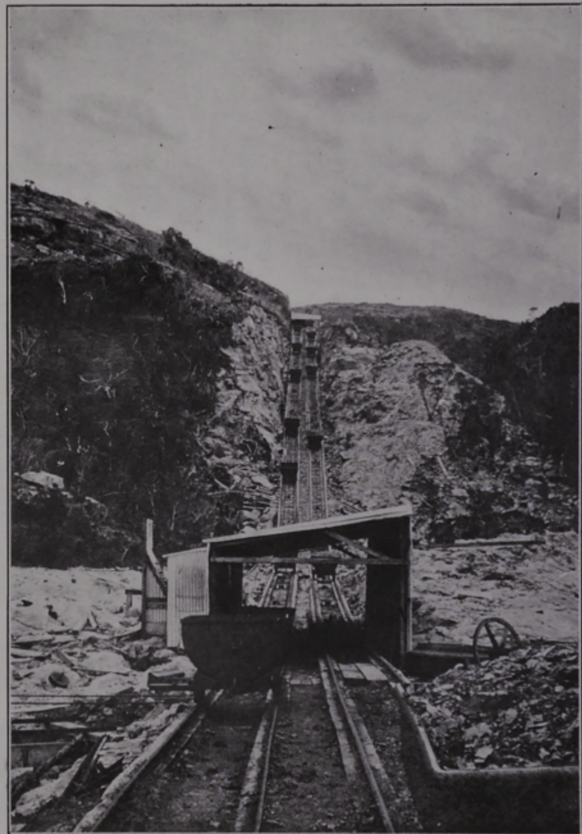
View looking up Tiroroa Reach, Buller Gorge.

Hawk's Crag Breccia on Roadside, Buller Gorge, East of Little Hawk's Crag. Note Stratification and Moderate Size of Angular Fragments. The Notebook is 6 in. by 4 in.

[*To face page 66.*



View from Top of D Incline, Westport-Stockton Mine. The Steep Drop is due to the Mangatini Roll-fault. Characteristic Upland Country in Middle Distance.



View from Foot of D Incline, Westport-Stockton Mine.

[*To face page 66.*

CHAPTER V.

GENERAL GEOLOGY.

AORERE SERIES.

Content.

THE pre-Tertiary sedimentary rocks of the subdivision in the main consist of argillites, greywackes, and hornfels, together with limited amounts of schist, and in this bulletin are placed in a Palæozoic series—the Aorere. Some puzzling gneissic rocks, which, as stated on another page, may in part represent highly metamorphosed sediments, are excluded from the Aorere Series, and are tentatively grouped with the igneous rocks.

Age and Correlation.

Von Haast does not make any definite statement concerning the age of the older sedimentary rocks in the Buller-Mokihinui Subdivision, but from his map of 1861* it

* See "Report of a Topographical and Geological Exploration of the Western Districts of the Nelson Province, New Zealand," 1861.

would appear that he regarded them as belonging to a Mesozoic period (probably the Triassic). Cox mentions "Triassic slates,"* without, however, giving any reason for the age-determination. McKay has always placed the older sedimentary rocks of the Westport district in the Maitai Series, which he considers to be of Carboniferous age.†

In the almost complete absence of fossils the age of the rocks here assigned to the Aorere Series remains uncertain, but the name adopted by the writers indicates that in their opinion a correlation with the Palæozoic strata of the Collingwood district is probable. Such a correlation has already been made by E. J. H. Webb in the case of lithologically similar rocks in the Mount Radiant Subdivision,‡ which are practically in continuity with the ancient sedimentaries of the Buller-Mokihinui Subdivision. These latter may with certainty be correlated with the North Westland rocks, assigned to the Kanieri Series in Bulletin No. 1, and to the Greenland Series in Bulletins Nos. 6 and 13. They also closely correspond to the auriferous rocks of the Reefton district, which for reasons previously stated by one of the writers§ are believed to be of pre-Devonian age.

The thesis that the bulk of the older sedimentary strata west of the Alpine Range in Nelson and North Westland belong to the Aorere Series, of Ordovician or Siluro-Ordovician age‖, and not to the Maitai Series, of probable Trias-Jura age, is one of great importance, both from an economic and a scientific point of view. Fortunately, the evidence obtained during the course of the recently completed geological survey of the critical Reefton area will, when fully pieced together, almost certainly be sufficient to resolve the uncertainty that exists at the time of writing. The data already available point strongly to the probability of the auriferous Reefton rocks being of pre-Devonian age.

Distribution.

As will be observed from the maps, the Aorere rocks are found almost entirely north of the Buller, and occur in irregular disconnected areas of all sizes. Discontinuity may either be real, and caused by intrusions from an underlying granitic magma, or may be due to a capping of Tertiary rocks, and therefore merely apparent. Aorere strata form a considerable part of Mount Kilmarnock and of the western slope of the Glasgow Range. Another area of some size extends from a point north of Mount Frederick into the valleys of Stony Creek and the Waimangaroa River. An extremely irregular mass of Aorere rocks, much disturbed by acid igneous intrusions, forms part of Mount William Range, whence it extends southward to the Buller River. It projects a wide tongue to the south-east, which reaches beyond the Mackley River. South of the Buller only two unimportant patches of Aorere strata are seen. One of these is east of the junction of the Ohikanui with the Buller, whilst the other, which is too small to be clearly indicated on the map, occurs seven or eight miles up the Blackwater River on the boundary-line between Hawk's Crag breccia and granite.

Structure.

Observations of dip and strike show that the Aorere rocks are everywhere strongly folded, the dip being seldom under 40°, and usually between 60° and 90°. Owing to

* "Report on Survey of Buller Coalfield." Rep. G.S. during 1874–76, vol. ix, 1877, p. 17.

† See for example his report "On the Geology of the Reefton District, Inangahua County," Rep. G.S. vol. xv, 1882, pp. 98, 99, 119, 131; and also "Geology of the South-west Part of Nelson and the Northern Part of the Westland District," Mines Report, 1895, C.-13, p. 27.

‡ N.Z.G.S. Bull. No. 11, 1910, p. 12. See also Bull. No. 3.

§ N.Z.G.S. Bull. No. 13, 1911, p. 49.

‖ Some pre-Ordovician rocks may be included in the Aorere Series as at present defined (see N.Z.G.S. Bull No. 3, p. 33), and it may also contain some strata of Silurian age.

cross-jointing, and more especially to the metamorphism induced by intrusive igneous rocks, the original bedding in many places is no longer discernible. For this and other reasons, such as faulting and the want of continuity in the various outcrops, the general structure is not easily deciphered. It is, however, apparent that the original direction of folding was in the north-west quadrant, and probably along north-north-west to south-south-east lines. A rough count shows that 64 per cent. of the observed strikes are in the north-west quadrant, and 36 per cent. in the north-east; but more of the latter strikes than of the former are obviously influenced by faults or by the post-Miocene uplift and tilting, which has notably distorted the pre-existing structure. Apparently, however, very little structural modification has been caused by the forces that produced the north-east to south-west folding seen in the Southern Alps.

In the Parapara Subdivision the structure of the Aorere rocks is similar to that in the Buller-Mokihinui area, the trend of the folds being north-north-west to south-south-east,* whilst in North Westland a north-west to south-east folding is again observable.†

Date of Folding.

As regards the time when the Aorere rocks were first subjected to folding, nothing definite can at present be said. It is probable, however, that folding accompanied the granitic intrusions, which, it is thought, took place in pre-Triassic times.‡ Possibly the first period of flexure was towards the end of the Jurassic, but this view almost necessarily implies a Maitai—that is, Trias-Jura—age for the rocks here classed as Aorere. It will be observed that the senior author, having now relegated the Greenland rocks to an Ordovician or Siluro-Ordovician period, has modified his opinion§ as to the time when the main folding of these rocks took place. His views with respect to direction and time of structural movements as expressed in Bulletin No. 6 have been adversely criticized by Marshall,‖ probably with justice as regards the date of folding, but the more important thesis advanced by Gregory¶ that in New Zealand a mountain system trending north-west to south-east preceded the formation of the Southern Alps and other ranges with a north-east to south-west trend is but little affected by Marshall's arguments. The post-Miocene movements may be regarded as attempts at folding, which had little effect on the structure of the Aorere strata beyond producing some degree of distortion.

Petrology.

The rocks of the Aorere Series may be described under the headings of (1) argillites, (2) greywackes, (3) hornfels, (4) schists.

(1.) *Argillites.*—Argillites are not well represented in the subdivision, but in most areas of Aorere rocks there are bands of sufficiently fine grain to be termed argillite. These bands are usually of a greenish colour, and have in many cases a silky sheen or lustre, due to extremely fine scales of muscovite or allied mica. The argillites are in places bleached by contact with the coal-measures. By metamorphic alteration they pass into hornfels and schist.

(2.) *Greywackes.*—Greywackes of much the same character as those seen in North Westland, but on the whole of somewhat finer grain, form the greater part of the Aorere rocks of the subdivision. They generally exhibit a bluish-grey or greenish-

* N.Z.G.S. Bull. No. 3, 1907, p. 34.

† See N.Z.G.S. Bull. No. 6, 1908, pp. 31, 36, 97; Bull. No. 13, 1911, pp. 49, 50; and P. G. Morgan in "A Note on the Structure of the Southern Alps," Trans., vol. xliii, 1911, pp. 276, 277.

‡ The occurrence of granite pebbles in the Triassic conglomerates of north Nelson is considered to justify the assumption of pre-Triassic granite intrusions in the Westport district.

§ See N.Z.G.S. Bull. No. 6, 1908, pp. 34, 35–37.

‖ "New Zealand and Adjacent Islands" (reprinted from Handbuch der regionalen Geologie), 1912, pp. 37–38.

¶ See P. Marshall's "Geography of New Zealand," 1905, pp. 12–13.

grey colour, but in places where overlying coal-measures containing a seam of coal have recently been removed by denudation a bleached zone appears. The bleaching is evidently due to percolating solutions containing organic acids derived from the original vegetable matter of the coal. The work of these acids has been assisted by the more or less weathered nature of the ancient rock-surface on which they acted.

Near the summit of Mount Frederick and in Happy Valley (about two miles to the eastward) masses of partly silicified greywacke show a peculiarly gnarled or twisted grain, which imparts to them a characteristic appearance, difficult to describe in a few words. Silicified greywacke also occurs north-west of Burnett's Face.

(3.) *Hornfels.*—Through the thermal metamorphism caused by intrusive granite the argillites and greywackes pass into hornfels. This is a dark-grey rock, with a peculiar sheen, due to the development of biotitic mica.* It has a considerable development on the slopes of Mount Glasgow, Mount Kilmarnock, and, in fact, wherever Aorere rocks are in contact with granite. In several places—for example, in Chasm and Welcome creeks—small masses of Aorere rocks have been recrystallized to such an extent that hand-specimens are with difficulty distinguished from fine-grained granite. Silicification may have accompanied recrystallization in some cases—as, for example, in the rock represented by No. 3 of the following analyses—but the evidence for introduction of silica is by no means conclusive, and it may well be true that the rocks in question were originally of a highly siliceous nature.

	(1.)	(2.)	(3.)
Silica (SiO_2)	57·45	69·90	76·65
Alumina (Al_2O_3)	23·78	14·30	11·78
Ferric oxide (Fe_2O_3)	0·58	0·20	0·20
Ferrous oxide (FeO)	6·64	4·83	3·22
Manganous oxide (MnO)	0·05	0·09	0·02
Lime (CaO)	0·50	0·65	0·75
Magnesia (MgO)	1·14	2·71	1·88
Potash (K_2O)	4·76	3·03	2·57
Soda (Na_2O)	1·08	0·70	0·90
Titanium dioxide (TiO_2)	0·02	0·57	0·02
Phosphoric anhydride (P_2O_5)	0·12	0·30	0·21
Loss at 100° C.	0·32	0·12	0·45
Water and organic matter	3·70	2·70	1·55
	100·14	100·10	100·20

No. 1. Hornfels from Chasm Creek, above Westport-Cardiff Mine.

No. 2. Hornfels from Chasm Creek, below Westport-Cardiff Mine.

No. 3. Sheeny hornfels from inclusion in granite, near Buller Coalfield Reserve boundary, Welcome Creek, Mokihinui.

The sedimentary origin of each of the samples analysed is confirmed by the dominance of magnesia over lime and of potash over soda in each case. In all, moreover, especially No. 1, the alumina is greatly in excess of the 1 : 1 ratio necessary to satisfy the alkalies present. Thus the principal chemical criteria for distinguishing metamorphic sedimentary rocks are satisfied.†

(4.) *Schists.*—Schistose argillite, greywacke, and hornfels occur in a number of places near great faults or granitic intrusions. In addition true mica-schist occurs to a limited extent in Hodges Creek, in the Upper Ngakawau Valley, and in New Creek. In

* See N.Z.G.S. Bull. No. 1, pp. 47–48; Bull. No. 6, p. 98; Bull. No. 11, p. 13. Several sections of Mokihinui hornfels show minute prisms of rich brown tourmaline scattered through the biotite.

† Edson S. Bastin: "Chemical Composition as a Criterion in identifying Metamorphosed Sediments." Journal of Geology, vol. xvii, 1909, pp. 445–72, and vol. xxi, 1913, pp. 193–201.

IRON TRESTLE, WESTPORT COAL COMPANY'S HAULAGE ROAD, DENNISTON. THE VIEW SHOWS NEARLY HORIZONTALLY BEDDED COAL-MEASURE ROCKS. THE ROAD TO THE OLD BANBURY MINE IS SEEN ON THE LEFT.

each of these localities the schist contains indefinite spots of a white mineral which is probably cordierite. Webb has noted a similar rock as occurring in the Mount Radiant Subdivision.* Small bands of schistose rock, apparently of sedimentary origin, are not uncommon in several parts of the gneissic complex found in the northern part of Mount William Range and over a wide belt of country to the eastward.† It has been found impossible to map these bands apart from the enclosing gneiss, but it is at least possible that they are remnants of a pre-Ordovician series, as tentatively suggested in Chapter III (page 59).

Metamorphism.

It is not necessary to describe in detail the thermal and thermo-dynamic metamorphism of portions of the Aorere rocks, the matter having been fully discussed in former bulletins. Reference, if desired, may be made to Bulletin No. 1, pages 64–65; Bulletin No. 6, pages 78–79; and Bulletin No. 11, page 13. The one point requiring comment is that in the Westport district, as in North Westland, metamorphism was apparently not accompanied to any notable extent by the formation of valuable mineral lodes.

Bituminous Coal-measures (Mawheranui or Waimangaroa Series).

CONTENT AND SUBDIVISION.

The bituminous coal-measures of the Buller-Mokihinui Subdivision consist of breccia, conglomerate, grit, sandstone, shale, and mudstone, together with a little limestone and the bituminous coal-seams to which they owe their economic importance. To the lowest member, which consists mainly of angular and subangular material, the name Hawk's Crag breccia has been given. Though locally of great thickness, the Hawk's Crag breccia has a restricted distribution, and nowhere, so far as known, does it actually underlie bituminous coal. Northward from the Buller Valley its relationships are obscure, though apparently it passes into an ordinary conglomerate. This latter rock near Mount Rochfort is of considerable thickness, but as a rule is not prominent elsewhere, and in places is absent. Above the horizon of the conglomerate comes a series of freshwater grits and coarse sandstones, alternating with shales and associated coal-seams. These strata, together with the underlying conglomerate, correspond to similar rocks near Greymouth, and in this bulletin, as in Bulletin No. 13, are called the Brunner beds. They are succeeded by the Kaiata beds, which are marine sediments consisting mainly of calcareous mudstone, with minor limestone, sandstone, and in one locality conglomerate. They correspond in character with the Kaiata mudstone near Greymouth, and in age with the same stratum plus the underlying Island sandstone. The following tabular statement shows the subdivisions of the bituminous coal-measures adopted in this bulletin.

Subdivision.	Content.	Estimated Thickness.	Remarks.
Kaiata beds	Calcareous mudstone; calcareous sandstone; limestone; conglomerate in minor amount	1,000 ft. to 1,500 ft. Original thickness greater	Owing to denudation full thickness is not shown in any one locality.
Brunner beds	Shales, sandstones, and grits with coal-seams; conglomerate	100 ft. to 500 ft. or more	Thickness decidedly variable.
Hawk's Crag breccia	Breccia; breccia-conglomerate; conglomerate, grit, sandstone, and shale in minor amount	3,000 ft. (?) ..	Maximum possible thickness given; actual thickness very variable.

* N.Z.G.S. Bull. No. 11, 1910, p. 12.

† Mr. Alexander McKay has verbally informed one of the writers that schist occurs at Moran's Water-race, near Addison's. This, however, may be a biotitic band in granitic gneiss. Several such bands, greatly resembling schist, occur near the locality (see p. 101).

CONDITIONS OF DEPOSITION.

Although there is strong evidence that at some period prior to the deposition of the bituminous coal-measures the Buller-Mokihinui Subdivision was part of a great peneplain, yet the characters of the Hawk's Crag breccia show that at the end of the Cretaceous, or at the beginning of the Tertiary, elevation of part of the land in or adjoining the subdivision had taken place. It is probable also that land extended for some, perhaps many, miles westward of the present coast-line. The peculiar conditions that gave rise to the Hawk's Crag breccia are discussed on other pages. The Brunner beds were deposited on a moderately level surface by a stream or streams that drained an area where granite and allied rocks predominated over sedimentaries. They are believed by the writers to be in great measure deltaic deposits formed in a shallow lake or lakes. The manner in which the coal-seams were formed will be discussed in Chapter VI.

Whilst the Brunner beds were being laid down the land gradually subsided, and at last marine conditions almost imperceptibly supervened. Subsidence continued for a long time, during which the Kaiata beds were formed. Finally sedimentation was interrupted by a more or less pronounced uplift, which is considered to have taken place some little time before the beginning of the Miocene period. The exact nature of the land-movement and of the resulting unconformity is somewhat doubtful, but the matter is an important one, and therefore will be more fully discussed on a later page.

AGE.

It is well known that numerous controversies have arisen in connection with the ages of the various New Zealand coalfields. Although the questions involved are of the highest importance from all points of view, yet it is regrettable that so much energy has been expended on discussion, whilst comparatively little detailed stratigraphical work has been done, and palæontological research remains in a backward condition. Though progress in these matters is now being made, the time for authoritative general statements has not yet arrived.

In 1861 von Haast tentatively assigned the bituminous coal-measures of the Westport district to the Oolite,* and at a later date was probably inclined to give them a Cretaceous age, but in deference to Hector's views decided to place them in the Cretaceo-Tertiary system.† Cox, in his reports published in 1877, did not definitely state the age of the bituminous coal-measures, although his sections show them to rest with a high degree of unconformity on rocks which he supposed to be of Triassic age.‡ Some years previously Hector had decided that the chief coal-bearing strata of New Zealand belonged to a Cretaceo-Tertiary system.§ Hutton, though it is said|| (apparently incorrectly) that he was the originator of the Cretaceo-Tertiary hypothesis, consistently opposed it, and from 1873 always assigned a Cretaceous age to the Buller and Grey-mouth coal-measures.¶ McKay has always agreed with Hector's classification. Park at one time supported the Cretaceo-Tertiary hypothesis, but for a number of years has

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* *Op. cit.*, pp. 105, 112.

† "Geology of Canterbury and Westland," 1879, p. 298.

‡ See G.S. Rep. No. 9, 1877, p. 17, and sections opposite p. 112.

§ See "On the Remains of a Gigantic Penguin. . . ," Trans., vol. iv, 1872, pp. 344–45; G.S. Rep. during 1876–77, No. 10, 1877, p. iv of Progress Report; &c.

|| Park: "The Supposed Cretaceo-Tertiary Succession of New Zealand." *Geological Magazine*, Dec. v, vol. ix, 1912, p. 491. Hector, however, claims the term "Cretaceo-Tertiary" as his own (Trans., vol. iv, 1872, p. 344), and Hutton in 1873 mentions "the Cretaceo-Tertiary formation of Dr. Hector" (Q.J.G.S., vol. xxix, p. 378). So far as the writers can ascertain, the term "Cretaceo-Tertiary" was first used in connection with New Zealand geology by Hector in "Abstract Report on the Progress of the Geological Survey of New Zealand during 1866–67," 1867, p. 8.

¶ "Synopsis of the Younger Formations of New Zealand." Q.J.G.S., vol. xxix, 1873, p. 377. See also "On the Relative Ages of the New Zealand Coalfields." Trans., vol. xxii, 1890, pp. 377–87.

been disposed to agree with Hutton. His assignment of the bituminous coal-measures of the Westport district to his Waimangaroa Series, which he considers to be of upper Eocene age* marks a departure from Hutton's views in detail rather than in principle. Marshall places the Westport coal-measures in the Oamaru Series, and considers them to be of Early Cainozoic age.†

Though identifiable fossils are not plentiful in the bituminous coal-measures, yet the palæontological data given on later pages justify the opinion that the Brunner and Kaiata beds are of Eocene age. In the case of the Hawk's Crag breccia there is some little uncertainty, conformity with the Brunner beds not being fully proved. Possibly the breccia is of Cretaceous age. One reason for thinking so is that it is intersected by lamprophyric dykes which apparently do not extend into the Brunner beds. Moreover, in the Blackball district, Greymouth, lamprophyric pebbles are found in a conglomerate at the base of the Brunner beds.‡

CORRELATION.

There is no difficulty in correlating the Brunner and Kaiata beds with corresponding strata in the Greymouth district. It has been indicated, however, that the Island sandstone of the Greymouth area has so small a development in the Buller-Mokihinui Subdivision that what there is of it is included in the Kaiata beds.

The Hawk's Crag breccia extends southward for a few miles, but whether its exact equivalent can be found anywhere else is doubtful. With it McKay correlates a similar rock found in the Waitahu Valley near Reefton.§ It may be tentatively correlated with the Koiterangi and Brunner conglomerates, which in some ways resemble it, and occur in a similar position with respect to the bituminous coal-seams. It is just possible that the Hawk's Crag breccia is contemporary with the basal conglomerate of the Paparoa beds,‖ in which case a moderate unconformity separates it from the Brunner beds and a fresh complication must be introduced into the geological history of the region. The Buller Series of Hector, supposed by him to be of Cretaceous age, is equivalent to the Brunner beds of this bulletin, together with the underlying Hawk's Crag breccia. The history of this term is given in the next section.

As a whole the bituminous coal-measures of the Westport district may be correlated with similar strata found in the Pakawau district and other localities in west and central Nelson, but it does not appear advisable at the present time to advocate a correlation with any of the coalfields on the east coast of the South Island.

NOMENCLATURE.

In 1877 Hector definitely placed the chief coal-bearing formations of New Zealand near the base of his Cretaceo-Tertiary System, whilst the Amuri group, constituting his Lower Greensand formation, he classed as inferior.¶ In 1879, however, considering that the bituminous coals of the West Coast, conformable members of the Cretaceo-Tertiary sequence,** were probably of Lower Greensand age, he placed them in his Lower Greensand formation below the Amuri group, an order to which he adhered in

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* "The Geology of New Zealand," 1910, pp. 101–107.

† "Geology of New Zealand," 1912, p. 190; "New Zealand and Adjacent Islands" (Handbuch der regionalen Geologie), 1912, pp. 27, 40, 67.

‡ N.Z.G.S. Bull. No. 13, 1911, p. 58.

§ "On the Geology of the Reefton District, Inangahua County." Rep. G.S. during 1882, No. 15, 1883, p. 143.

‖ See N.Z.G.S. Bull. No. 13, 1911, pp. 50, 51, 86, &c.

¶ G.S. Rep. during 1876–77, No. 10, 1877, p. iv of Progress Report. See Progress Reports in G.S. Rep. Nos. 8 and 9 for earlier references to the Cretaceo-Tertiary System. Still earlier references have already been given.

** "Handbook of New Zealand" (Sydney International Exhibition), 1879, pp. 21 22.

1884.* In 1881† and 1886‡ Hector, so far as can be gathered from his published classifications, reversed this order and placed the bituminous coals and associated sandstones, grits, and conglomerates, which in 1884 he had designated the Buller Series, again above the Amuri Series.

Meanwhile, in 1885,§ McKay, following Hector's classification of 1884, correlated his "woodsands" of the Amuri Bluff district, which underlie the Amuri Series, with Hector's Buller Series, and in 1890|| maintained this correlation despite Hector's reversal of the relative positions of the two series in his table of formations of 1886. Probably by reason of this confusion the name "Buller Series," originally applied to the bituminous coals of the West Coast, with their associated sandstones, grits, and conglomerates, dropped out of use after 1890.

In 1910 Park proposed the name "Waimangaroa Series," to include the whole of the bituminous coal-measures, the term being, he considered, appropriate both from the standpoint of the miner and of the geologist.¶ In the Greymouth district, however, the bituminous coal-measures are more fully and typically developed than in the Westport district, and therefore in 1911 one of the present writers suggested the name of "Mawheranui Series,"** derived from the Maori name for the Grey River. In this bulletin the somewhat awkward term of "bituminous coal-measures" is used, so as to leave the way open for a settlement of the question of nomenclature by a conference of New Zealand workers in geology.

DISTRIBUTION.

The bituminous coal-measures outcrop irregularly over a belt of country about thirty-two miles in length with a maximum width of ten miles, which extends from somewhat north of the Mokihinui River to the south-east corner of the subdivision. They cover in all about 137 square miles, but a considerable portion of this area does not carry coal, and of the remainder only twelve square miles has been definitely proved to contain workable coal. Future exploration, however, may be expected to add appreciably to the latter estimate. As will be observed from the maps, inliers of older rocks appear in many places, and there are also various outliers of the coal-measures themselves, especially in the Mackley Valley. South of Mount Rochfort denudation has almost entirely removed the coal-bearing portion of the measures, so that the outcrops are mainly barren Hawk's Crag breccia. An isolated outcrop of bituminous coal appears at Moran's Water-race, near Addison's, but southward of this the coal-bearing beds are not again seen on the western slope of the Paparoa Range until a point in the Fox River watershed three or four miles beyond the southern boundary of the subdivision is reached.

Bituminous coal-measures underlie Miocene rocks in part of the area that lies seaward of the Kongahu fault, but their extent can be ascertained only by the costly process of boring. They also underlie Miocene strata in two comparatively small areas, one north of the Mokihinui River and the other in the Mackley watershed. In neither of these localities is the presence of workable coal more than a possibility.

STRUCTURE.

The bituminous coal-measures are much affected by faulting, warping, and tilting, but are nowhere folded with any degree of regularity. Their more important structural

* G.S. Rep. during 1883–84, No. 16, 1884, p. xiv of Progress Report.

† G.S. Rep. during 1879–80, No. 13, 1881, pp. iii–iv of Progress Report.

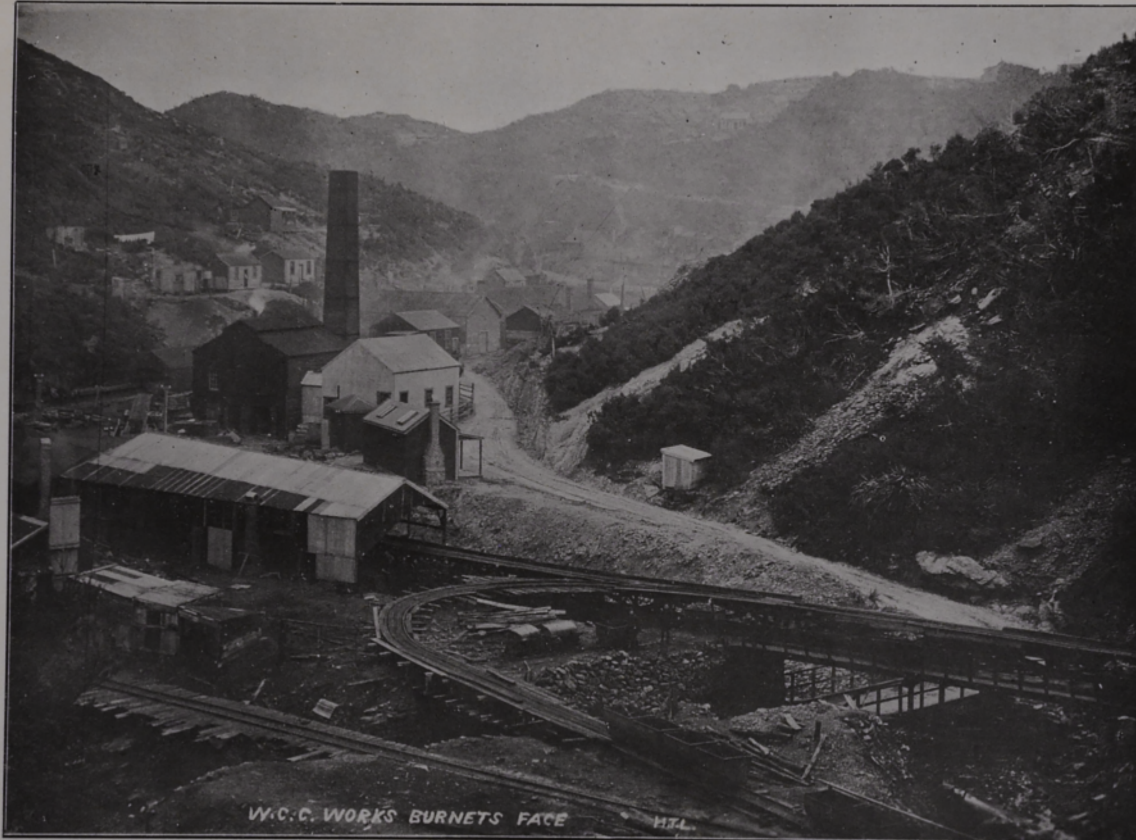
‡ "Indian and Colonial Exhibition, London, 1886, New Zealand Court: Detailed Catalogue and Guide to the Geological Exhibits," p. 39.

§ G.S. Rep. during 1885, No. 17, 1886, p. 68.

|| G.S. Rep. during 1888–89, No. 20, 1890, p. 146.

¶ "The Geology of New Zealand," 1910, p. 107.

** N.Z.G.S. Bull. No. 13, 1911, pp. 53–54.



Burnett's Face Township. An Outcrop of Aorere Rocks appears on the Roadside opposite the Chimney-stack; Coal-measure Rocks form the Higher Ground.

features are connected with the formation of the Paparoa-Papahaua earth-block, which has already been somewhat fully described (see pages 48–9). Thus the main coal-bearing area—namely, that extending from Mount Rochfort to the Mokihinui River—is an uplifted block, tilted to the east, and as a whole pitching to the north. There are, however, many minor warps and other irregularities in the block. For example, from Mount Rochfort, which may be regarded as the summit of an unsymmetrical dome, there is a pitch to the southward, and also a pitch to the northward as far as Denniston. Beyond the Waimangaroa River the pitch is reversed, so that the coal-measures rise till the summit of Mount Frederick (3,621 ft.) is reached. From Mount Augustus, two miles to the north of Frederick, the pitch of the block is again northerly. A domal structure appears at the gorge of the Ngakawau River, the summit of the dome being at trig. station AN (1,728 ft.). Charming Creek valley is an area of structural depression, east of which is another domal area, the summit of which is marked by trig. station AR (1,445 ft.), whilst to the north is a ridge, beyond which a northerly pitch is resumed. Thus at the Mokihinui River the bituminous coal-measures, as in Charming Creek valley, reach sea-level, and disappear beneath a cover of Miocene rocks.

Along the western margin of the Papahaua block it will be observed that from Wright or Coal Creek to Stony Creek, north of Waimangaroa, the coal-measures have a varying westerly dip, which reaches 90° near the Kongahu fault zone. From Stony Creek to Granity no westerly-dipping beds are visible, denudation having removed those that may once have existed on the extremely steep western slopes of Mounts Frederick and Augustus. From Granity to Ngakawau westerly-dipping beds, more or less involved in the Kongahu fault, again appear.

Towards the east the dip of the Papahaua block in that direction is interrupted by the relative uplift due to the Mount William fault. On the crest of the Mount William Range the remnants of the coal-measures pitch alternately north and south, following the surface relief, whilst the outliers on the eastern side of the range dip more or less with the slopes. Mount Stockton (2,451 ft.) is a gneissic dome from which the coal-measures have been removed by erosion. Viewed broadly, it is a continuation of the Mount William Range, and the domed area near trig. station AN perhaps comes into the same category. The gneissic ridges on which trig. stations AS and AD are situated also represent areas of elevation from which the coal-measures have been eroded.

The somewhat irregular attitude of the bituminous coal-measures indicated by the gently dipping remnants between the northern part of the Mount William Range and the Blackburn does not need detailed description. A similar moderately irregular or undulating structure appears in the Blackburn area itself and in the Mackley watershed to the south. As the great Glasgow fault is approached the coal-measures dip with considerable uniformity towards it, and thus the higher or Kaiata beds make their appearance near the fault, and cover to a considerable depth the Brunner beds, together with any coal-seam that may be present.

In the Buller Gorge and in the valley of the Blackwater the Hawk's Crag breccia has a strike varying from west-north-west to north-north-east. Except at the head of Nada Creek, where a north-easterly dip is seen, the dip is westerly or south-westerly, and generally between 15° and 25°, though in places near faults it may reach 50° or 60°. It is noteworthy that along the Tiroroa reach of the Buller the strike is west-north-west, parallel to the river, whilst elsewhere the strike generally approaches within 30° of the meridian. The chief faults traversing the breccia have upthrow to the westward or south-westward, so that the effect of dip in those directions is more than counterbalanced.

Some of the numerous faults that traverse the coal-measures have been described in Chapter IV, and others will be mentioned in that part of Chapter VI which deals with bituminous coal.

PETROLOGY AND GENERAL ACCOUNT.

The bituminous coal-measures, as shown in the table on page 71, have been subdivided into three groups—(1) Hawk's Crag breccia; (2) Brunner beds; and (3) Kaiata beds. These will be separately described in order of age.

(1.) *Hawk's Crag Breccia.*

The Hawk's Crag breccia consists of an immense thickness of angular and subangular blocks of varying size, the interspaces filled with finer material, and the whole cemented by a ferruginous paste, through the oxidation of which the breccia acquires a characteristic reddish or purplish colour. In a few places there are layers which approach conglomerate and there are also minor bands of shale and sandstone. The angular blocks, as a rule, are under 1 ft. in diameter, but in several localities huge boulders are conspicuous. East of Little Hawk's Crag, where the breccia is first seen by travellers from Westport, comparatively small blocks, mostly under 5 in. in diameter, of more or less schistose greywacke, argillite, and allied rocks, form the bulk of the rock. A little farther to the east, near the tunnels through which the Buller Gorge road passes, large boulders may be seen in the outcrop on the river-bank. Hereabouts some granite appears in the breccia, and becomes plentiful a few chains to the eastward. From Tiroroa (Twelve-mile) to Hawk's Crag there is usually a considerable proportion of granite in the breccia. Some distance to the east of Tiroroa enormous boulders are present. In Hawk's Crag itself and in the lower part of Hawk's Crag Creek granite is not by any means prominent, but towards the head of the creek rapidly becomes plentiful, and in one place forms nearly the whole of the breccia. The other rocks represented in the breccia of Hawk's Crag Creek are greywacke, argillite, hornfels, and schist of various kinds. In the Blackwater River and its tributaries granite generally forms from one-third to one-half of the breccia, most of the large boulders being of that rock, especially in the more southerly exposures. Other constituents are those mentioned above as occurring in Hawk's Crag Creek.

Material that may be described as breccia-conglomerate is prominent in the middle part of Blackwater River and its tributary Nada Creek. It passes into an ordinary conglomerate in which grit, sandstone, and even shale bands may be observed. In places it is difficult to determine whether Miocene beds are or are not present, for there is no reliable criterion by which they may be distinguished from the very similar Eocene rocks.

Origin.—In some respects the Hawk's Crag breccia resembles a morainic deposit, and McKay, when dealing with the geology of the Inangahua district, has therefore suggested a glacial origin.* The chief evidence for this view is afforded by the presence of angular material of all sizes. The very abundance of these angular blocks, however, considered in conjunction with the entire absence of rounded pebbles in some places, and the comparative scarcity of fine material, in itself gives rise to a difficulty in accepting the view that they have been transported by ice. Nowhere has the breccia the appearance of typical glacial drift, and nowhere can striated pebbles or fluvio-glacial gravel be found. Thus the chief criteria for glacial deposits are not applicable to the case under consideration. The breccia, however, does possess many of the

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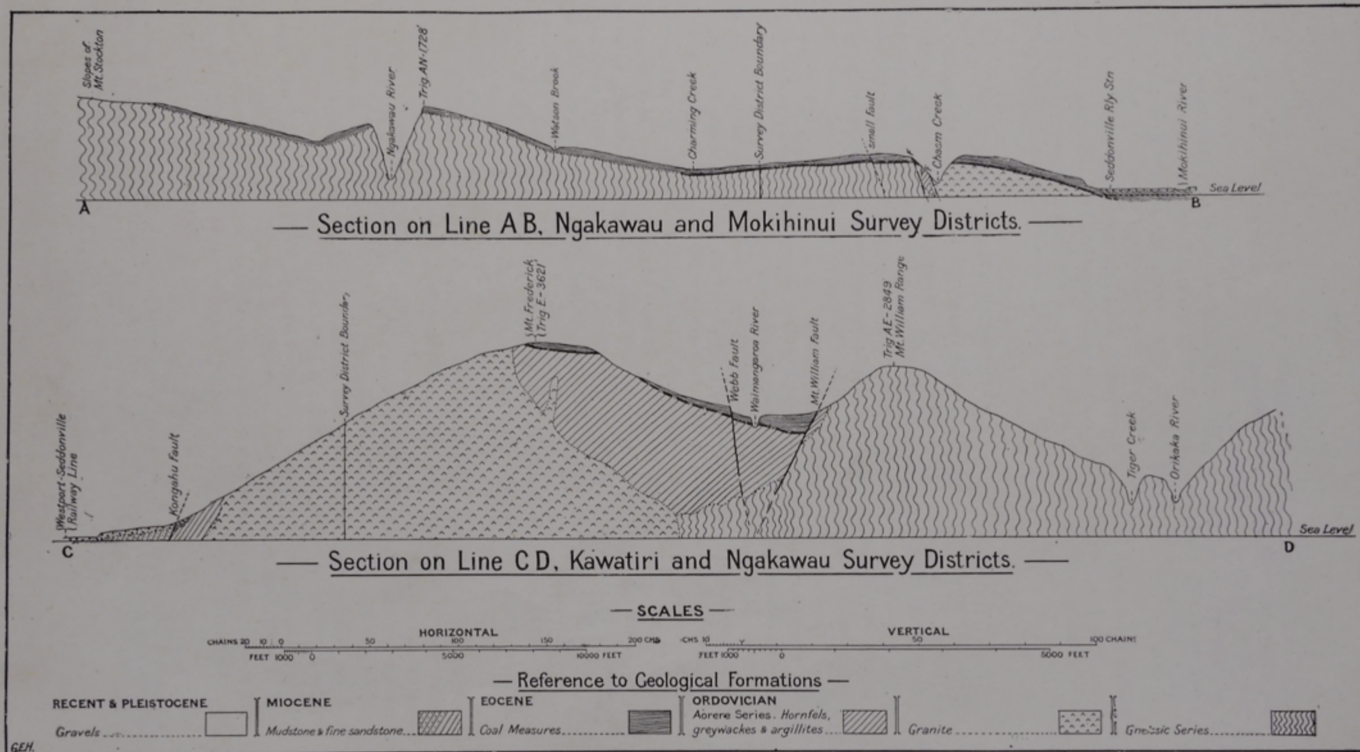
* "On the Geology of the Reefton District, Inangahua County." G.S. Rep. during 1882, No. 15, 1883, pp. 142–4.



[To face page 76.

features of a pluvial deposit,* and this, with the addition of more or less true talus, it is considered to be. In particular, the rapid change in composition observable at various places is characteristic of talus or pluvial rather than of fluviatile or glacial deposits, and proves the local origin of the chief constituents. In order to account for the abundance of small angular fragments it must be supposed that they have been derived from zones of crushed rock, which were probably due to great faulting movements immediately previous to the formation of the breccia.

Rocks that strongly resemble the Hawk's Crag breccia have a great development in the Brighton and Waiwhero survey districts, south of the subdivision, and also occur near the head of Boatman's Creek and in the Waitahu Valley. These occurrences will be described in the forthcoming Reefton bulletin (No. 18).

(2.) *Brunner Beds.*

The Brunner beds consist of conglomerate, grit, sandstone, and shale, with coal-seams. They are considered to be entirely of fresh-water origin, but it should be noted that in places a coarse sandstone not far above the coal may possibly be marine. The lowest stratum, the conglomerate, is not everywhere present, and in many places is of no great thickness: thus lenticularity, as is usually the case with deposits formed mainly of coarse material, is a conspicuous feature. The conglomerate has its greatest development south of Mount Rochfort, where the thickness is some hundreds of feet The upper layers contain much quartz, but in the lowest horizon pebbles of other rocks are plentiful. Towards the Buller the Rochfort conglomerate is supposed to pass into the Hawk's Crag breccia, but this is somewhat doubtful, and possibly it rests upon the breccia with some degree of unconformity. Conglomerate has a moderate development on the western slopes of Mount Rochfort, but is almost or quite absent near Burnett's Face, Mount William, and Mount Frederick. It is again present in Fly Creek and in most localities to the northward as far as Mokihinui River. In Charming Creek valley diamond drilling has proved from 3 ft. to 64 ft. of conglomerate, whilst near Mokihinui Mine at least 50 ft. of quartzose conglomerate is exposed, and a similar rock is also seen at various spots between the northern part of Mount William Range and the Blackburn Stream.

Quartz predominates among the pebbles in the conglomerates of the Brunner beds, with greywacke and granite next in order of abundance. Other constituents are hornfels, argillite, gneiss, and schist.

More uniformly distributed than the conglomerate are the grits, which usually appear both above and below the main coal-seam. The lower grits are usually noticeably coarser in grain than the upper grits, and this feature may to some extent be used in distinguishing the two horizons. It is not an infallible criterion, however, for fine grit occasionally appears below the coal, and not infrequently coarse grit is found in the upper horizon. Again, in places coal may be quite absent, and in that case the appearance of the grits is no guide to the locus of the coal horizon. The thickness of the grits, both above and below the main coal-seam varies greatly. In a few places there is no grit below the coal, and in Coal Creek, near Mokihinui Mine, there is only a foot or two of grit above the coal. In various localties, particularly where there is little or no coal, cliffs of grit 100 ft. or more in height appear. These frequently show current bedding to a remarkable extent.

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* Pluvial deposits are defined by Arthur C. Trowbridge as "those transported by rain-water or immediate run-off, without the agency of permanent streams." See "A Classification of Common Sediments and some Criteria for Identification of the various Classes": The Journal of Geology, vol. xxii, No. 4, May–June, 1914, p. 421. See also pp. 425–27, and especially illustrations on p. 426.

The quartz grains of which the grits are almost entirely formed have probably been derived mainly from areas of granite, gneiss, and quartz-porphyry. The remaining constituents are a few scales of mica together with scattered fragments of feldspar and other minerals. As a rule the feldspar is intermixed with quartz, and evidently derived from granite or gneiss.

By decrease in the size of the constituent grains the grits pass both vertically and laterally into sandstones, which are seldom of any great thickness. Interbedded with the grits and sandstones are moderately persistent bands of shale, which in many cases are associated with coal-seams. Some shaly beds laterally pass into or are replaced wholly or partly by coal, whilst others through increasing coarseness of the constituents grade into sandstone, and finally into grit. The variability and especially the lenticular character of the rocks included in the Brunner beds are indeed remarkable features. This statement applies also to the coal-seams, as will be perceived from a perusal of the next chapter.

(3.) *Kaiata Beds.*

The Kaiata beds consist almost entirely of a dark-coloured marine mudstone or claystone, which is everywhere calcareous, and usually, especially in the lower horizons, more or less sandy and micaceous. The lowest portion in places passes on the one hand into a fine-grained sandstone, and on the other into a limestone. Calcareous concretionary nodules are of common occurrence. Where, through overlap, the Kaiata beds are resting on pre-Tertiary rocks, a little grit or conglomerate may form the basal layer. In one exceptional locality—Waimangaroa—layers of conglomerate, grit, and sandstone are interbedded with the typical mudstone.*

Owing to denudation during pre-Miocene and again during Quaternary times, it is not possible to determine the original thickness of the Kaiata beds. If, however, it were true that no unconformity separated the bituminous coal-measures from the Miocene, the full thickness would appear in the area north of the Mokihinui, where the Kaiata rocks disappear under Miocene strata. Unfortunately, the structure in this locality is so irregular that no trustworthy estimate can be made, and all that can be said is that the thickness of the beds is probably over 1,000 ft. and under 1,500 ft. What is possibly a full section is again exposed on the Denniston Road east of Waimangaroa, where a thickness of from 1,000 ft. to 1,200 ft. is indicated. Faulting, however, here introduces an unknown factor.

The distribution of the Kaiata beds is determined by the general structure of the Papahaua sub-block. Owing to the soft nature of the mudstone which forms the chief member, denudation has removed them from the higher levels, and therefore they appear only in the downwarped portions of the block and in isolated patches along its faulted western margin. Thus the Kaiata beds are largely developed on both sides of the Mokihinui River near Seddonville, whence they extend along the western side of the Glasgow fault to the south of the Mackley. Here they apparently thin out against a pre-Tertiary land surface, either through overlap or by pre-Miocene denudation. A minor extension passes under Miocene rocks, but even this undoubtedly thins out to the southward. A belt of Kaiata mudstone somewhat over five miles long and about a quarter of a mile in average width is found along the western margin of the Mount William fault from a point west or north-west of trig. AE to the head of Cascade Creek. Other developments of Kaiata rocks are in the western part of the structural depression occupied by Charming Creek, and in three narrow separated belts more or less involved in the Lower Buller fault (1) between Ngakawau and Granity, (2) from Stony Creek to Whareatea River, and (3) in Deadman Creek.

* The Kaiata mudstone in Deadman Creek contains one or two pebbly bands. In Bradley Creek (north of Granity) and near Ngakawau (see fig. 8) interbedded grit and sandstone occur.

Entrance to a Tunnel, Westport–Stockton Mine. The View shows a Coal-seam overlain by Sandstone and Grit.

Coal Outcrop in C Section of Westport-Stockton Company's Lease.

[*To face page 78.*

As already stated, calcareous mudstone is the prevailing rock in the Kaiata beds, and its general nature has already been indicated. As a rule its stratification is obscure, but it has perhaps a slightly greater tendency to show bedding than the corresponding mudstone near Greymouth, from which, however, it differs in no important feature. No analysis of the Buller-Mokihinui mudstones is available, but reference to the analysis of Kaiata mudstone, quoted in Bulletin No. 13 (page 95), may be made.

Dark-coloured micaceous sandstone, moderately fossiliferous, occurs to a limited extent south of Mokihinui Mine, in the Mackley Valley south-east of trig. J, and in a few other places. The hard gritty sandstone seen in the lower portions of St. Andrew and St. David streams may belong either to the lower horizon of the Kaiata beds or to the upper part of the Brunner beds. On the east side of Mount Berners (trig. AD), near the Mokihinui–Lyell track, a dark sandstone, highly calcareous from the remains of Lithothamnion or allied alga, outcrops. A similar rock, approaching arenaceous limestone, appears in St. David Stream, whilst in St. Andrew Stream not far from the Glasgow fault a stratum of argillaceous limestone is visible. In a small area near the head of Fletcher Brook is an almost pure limestone, composed mainly of the remains of calcareous algæ. An analysis of this rock is given on page 128.

The coarse-grained rocks already mentioned as interbedded with mudstone near Waimangaroa require some further mention. They are best seen on the Denniston Road about three-quarters of a mile south-east of Waimangaroa Junction railway-station, where a quarry has been opened in a bed of conglomerate about 36 ft. thick, which has a strike of 236° and a dip approaching 90°. This is succeeded in downward order to the eastward by a few feet of alternating grit and comglomerate, which give place to sandy mudstone. This continues for some distance, but contains one layer of conglomerate, besides a few minor pebble bands, sandy layers, and isolated stones. Some 8 or 10 chains from the main conglomerate band a layer of grit and sandstone 20 ft. or more in thickness is visible, and this is followed by ordinary Kaiata mudstone. The main conglomerate band first mentioned persists to the north or north-north-east, and is again seen on the north bank of the Waimangaroa River, at a point where the stream makes a strong bend. Here it strikes 200°, and dips 65° to the north-west.

No satisfactory explanation of the presence of conglomerate in an upper horizon of the Kaiata beds can be given. It seems more likely that the constituent pebbles, consisting of granite, schist, gneiss, carbonaceous argillite, greywacke, and quartz, came from the west than from any other direction. In that case the presence of more or less elevated land in that direction during the Eocene must be assumed, a supposition which is not favourable to the seaward extension of the Buller coalfield.

PALÆONTOLOGY.

Plants.

The shaly layers of the Brunner beds in some places exhibit plant-remains, the most prominent of which are impressions of monocotyledonous and dicotyledonous leaves.

As a rule these are not well preserved, and are rarely even generically identifiable. The best locality for leaf-impressions observed during the course of the survey is about half a mile south-west of Seddonville railway-station, at the entrance to some old workings of the Westport-Cardiff Coal Company. Here, in a shale forming the roof of a 10 ft. coal-seam, *Cinnamomum* sp. (probably also found at Brunner) and *Aralia* (?) sp. were noted. On the Yellow Silver-pine Exploration Company's tram south of Chasm Creek dicotyledonous leaves, probably of *Fagus*, occur in a dark sandstone (base of Kaiata beds) associated with marine fossils. Leaf-impressions and other plant-remains (mainly fucoid casts) are not uncommon in the lower horizon of the Kaiata beds, but are rarely generically recognizable. Owing to the general poorness of the fossil vegetation and the lack of authoritative descriptive literature no serious attempt was made to collect plant-remains, and all that can be said is that the fossil leaves of the Brunner and Kaiata beds bear a general resemblance to those found in the Brunner horizon near Greymouth.

The limestones of Fletcher Brook and St. David Stream, together with the calcareous sandstone east of Mount Berners, abound, as already mentioned, in the remains of algæ, which probably represent one or more species of *Lithothamnion*.

Fauna.

The Kaiata beds in a number of places yield a somewhat scanty marine fauna, the individuals of which are generally in a poor state of preservation. The following list contains all identifications made to date. Except where there is a statement to the contrary, the fossils mentioned were collected by one or other of the writers. Most of the molluscan determinations are by Mr. Henry Suter.

Foraminifera.

Foraminifera are not uncommon throughout the argillaceous and calcareous members of the Kaiata beds. Sections of the Fletcher Creek limestone show the presence of several species. One of these belongs to the *Nummulinidæ*, and appears to be closely allied to *Amphistegina*. The test, however, is strongly inequilateral, and therefore suggests *Hemistegina*

A few individuals with diameters of about $\frac{1}{10}$ in. were extracted from the Kaiata mudstone in Tobin Creek valley and Chasm Creek. These were sent for examination to Mr. F. Chapman, of Melbourne, who, however, has not yet reported upon them.

Anthozoa.

One or more species of *Flabellum* occurs in the Kaiata mudstones of Chasm and Kiwi creeks. Fragments of a small madreporarian coral occur in the Fletcher Brook limestone.

Euechinoidea.

Remains of sea-urchins are fairly abundant in Tobin Creek and Chasm Creek valleys. Among these a species of *Schizaster* (cp. *S. exoletus* Hutton) may be identified. Mr. Sydney Fry, in a verbal communication, has stated that *Kleinia conjuncta* Hutton occurs in the valley of Mine Creek, near Ngakawau.

Pelecypoda.

Ostrea (*Eostrea*) *wuellerstorfii* Zittel. Occurs in dark sandstone, Yellow Silver-pine Exploration Company's tram, south of Chasm Creek. A very large specimen, con sisting of an accumulation of left valves, in the Geological Survey collections, is recorded as collected by Hector in 1871 between the Ngakawau and Mokihinui rivers (Loc. 281). Possibly the same species occurs in the Mackley River, about 35 chains south-east of trig. J. Here and near Chasm Creek the horizon is at the base of the marine beds.

Ostrea nelsoniana Zittel. Yellow Silver-pine Exploration Company's tram, south of Chasm Creek.

Ostrea sp. n.d. Blackburn River.

Cox* and Denniston† report micaceous sandstone with fossil oysters in the Blackburn Valley, which they call Tio or Orikaka Valley, the latter name being an error.

* "Report on Survey of Buller Coalfield." Rep. G.S. during 1874–76, No. 9, 1877, pp. 116, 117.
† "Detailed Notes on the Buller Coalfield." *Op. cit.*, p. 169.

This may be the same occurrence as that mentioned by McKay* in the words "From grits outcropping farther to the south of Chasm Creek Mr. Denniston collected a large oyster, *Ostrea carbonacea* (Hector MS.)."

Pecten hochstetteri Zittel. In lowest horizon of Kaiata beds between Burnett's Face and Kiwi Compressor (on western boundary of Ngakawau Survey District).

Pecten (Amusium) zitteli Hutton. Mackley River south-east of trig. J; Tobir Creek Valley; Mokihinui River above Seddonville; Chasm Creek (recorded by McKay)

Pecten (Chlamys) williamsoni Zittel. Mackley River south-east of trig. J, in low horizon of Kaiata beds.

Pecten fischeri. Reported by Cox in black marls (Kaiata mudstone).

Pecten sp. n.d. St. Andrew Creek (a small specimen).

Melina zealandica (Hutton) Suter. Tram-line south of Chasm Creek.

Trigonia sp. (?). Tram-line south of Chasm Creek (a fragment).

Pholadomya neozelanica Hutton. Mackley River south-east of trig. J.

Mactra sp. (young) (?). Mackley River south-east of trig. J.

Chione sp. (?). Mackley River, south-east of trig. J.

Cardium brunneri Hector. In lowest horizon of Kaiata beds between Burnett's Face and Kiwi Compressor.

Cardium sp. (?). What is apparently a small *Cardium* occurs in the Mackley River south-east of trig. J. It may be the same as a *Cardium* occurring in the Greymouth district near Runanga and at the Ten-mile Creek (See Bulletin No. 13, page 61). McKay states that Denniston collected a species of *Cardium* south of Chasm Creek (? Blackburn Valley).† *Cardium* may also occur in Mine Creek, near Ngakawau (verbal communication from Mr. S. Fry).

Lima (Limatula) bullata (Born.). Tobin Creek Valley. A Recent species.

Teredo sp. Teredo-bored material (once wood) was collected from a mudstone face in Chasm Creek a short distance below Tate Creek junction.

Scaphopoda.

Dentalium sp. A small species of *Dentalium* occurs in the Mackley River south-east of trig. J. It is probably the same as that recorded in Bull. No. 13 (page 62) as found near Brunner and at the Nine-mile Bluff in Island sandstone.

Gasteropoda.

Turritella pagoda Reeve. Tram-line south of Chasm Creek. A Recent species.

Turritella sp. McKay records from the neighbourhood of Chasm Creek "a small species of *Turritella*, resembling that found in the roof of the coal at Whangarei."‡

Turritella sp. (cp. *ambulacrum* Sowerby). Mackley River south-east of trig. J.

Scalaria (?) sp. n.d. Cox records *Scalaria* as occurring in the "black marls." This is probably one of the species of *Turritella* mentioned above.

Crustacea.

Calcareous remains doubtfully referred to a small crustacean are not uncommon in the Kaiata mudstone in the valleys of Tobin, Chasm, and St. Andrew creeks.

Summary.

The marine fossils of the Kaiata beds undoubtedly indicate a Tertiary age for the bituminous coal-measures. They show no affinities with the fauna of the Amuri Bluff

* "On the Mokihinui Coal Company's Property." Rep. G.S. during 1890–91, No. 21, 1892, p. 88.
† *Op. cit.*, p. 88.
‡ *Op. cit.*, p. 88.

and other Cretaceous localities, and therefore the correlation of the Buller Series with some of the lower beds at Amuri Bluff may be definitely dismissed. The fossils so far identified do not perhaps clearly indicate to what period of the Tertiary the bituminous coal-measures ought to be referred, but their position—probably an unconformable one—below Miocene strata and the paucity of Recent species justify their assignation to the Eocene.

Oamaru Series.

CONTENT AND SUBDIVISION.

Above the bituminous coal-measures as defined in the last section comes a series of conglomerates, grits, sandstones, limestones, claystones, and other rocks, which are regarded as being of Miocene age, and as approximately equivalent to the Oamaru System of Hutton. The total thickness of these beds cannot be exactly estimated, but probably exceeds 3,000 ft. They may be subdivided as follows:—

(3.) *Upper Beds:* Claystone and sandstone. Thickness, 1,200 ft. to 2,000 ft. or more.

(2.) *Middle Beds:* Limestone, claystone, and sandstone. Thickness, 300 ft. to 600 ft.

(1.) *Lower Beds:* Sandstone, grit, shale, and conglomerate, with seams of brown coal and lignite. Thickness, 50 ft. or less to 500 ft. or more.

This three-fold division of the Oamaru Series, a course previously followed in Bulletin No. 3 (Parapara) appears to be the most suitable for the west coast of the South Island. Its value as a classification depends largely upon the validity of the assumption that the limestone generally present is everywhere in approximately the one horizon, and marks the period when the depth of the Miocene sea in the area of deposition was at its maximum. The palæontological data obtained seem to justify this assumption (see later pages).

CONDITIONS OF DEPOSITION.

After the Eocene there was considerable elevation of the land, but this was speedily followed by long-continued depression lasting throughout the Miocene. In some parts of New Zealand Oligocene and Miocene strata may well have succeeded Eocene rocks without any unconformity, but so far as can be ascertained this was not the case on the west coast of the South Island.* Thus the lowest portions of the Oamaru Series in the Westport district are found to have been deposited by fluviatile agencies upon a sinking land-surface which was by no means level, and composed in some places of Eocene coal-measures, in others of pre-Tertiary rocks. As depression continued the sea invaded the land, and deposition of the marine sediments that form the middle and upper beds followed. Littoral and estuarine conditions, however, were prevalent, as is shown by the predominance of sandstone, together with grit or pebble bands, in most horizons. The impure nature of the limestone in various localities, and the overlap of the higher beds on the pre-existing land-surface, also indicate shallow-water sedimentation.

After the period of limestone-formation, deposition began to overtake depression, so that shallow-water and littoral conditions became increasingly prominent towards the close of the Miocene. There are a few pebbly layers in the Upper Oamaru beds of the subdivision, but the fluviatile Moutere or Old Man gravels, which in the Greymouth district conformably succeed the marine Blue Bottom, are not represented.

* P. G. Morgan: "Unconformities in the Stratified Rocks of the West Coast of the South Island." Trans. vol. xlvi, 1914, pp. 270–278.

AGE AND CORRELATION.

As shown on another page under the head of "Palæontology," the Oamaru rocks of the Buller-Mokihinui Subdivision contain a typical, though not varied, assortment of Miocene fossils. There is, however, room for a strong suspicion that the lowest beds approximately correspond in age with the Oligocene of Europe. Correlation with Oamaru rocks in other parts of New Zealand may also be based on stratigraphical and lithological grounds. Thus the Oamaru Series of the Buller-Mokihinui Subdivision is continuous with Webb's Kongahu Series.* Its upper claystones and sandstones correspond to the upper Kongahu Formation, whilst the middle and lower beds are approximately contemporaneous with the lower Kongahu Formation, with the exception that the lowest horizon is apparently not represented in the Mount Radiant Subdivision. The Oamaru Series as developed in the Westport district may also be closely correlated with the similarly named rocks in the Parapara district described in Bulletin No. 3, and with the Greymouth Series of Bulletin No. 13. The lower beds correspond to the Omotumotu beds of Bulletin No. 13; the middle beds to the Port Elizabeth beds and the Cobden limestone; the upper beds to the Blue Bottom Formation.

It is more or less feasible to make a correlation between the various subdivisions of the Oamaru Series on the west coast of the South Island and the subdivisions adopted for the same series as developed on the eastern side. For example, the lower beds may be correlated with the strata containing the brown coal of the Mount Somers, Oamaru, and Green Island districts; the middle claystone and limestone with the Waihao beds and the Oamaru stone; the upper claystone and sandstone with the Awamoa beds, and probably with the typical Pareora beds.

DISTRIBUTION.

Oamaru rocks cover a considerable area north of the Mokihinui River, whence, as already mentioned, they extend into the Karamea district. An apparently isolated coastal strip which has its centre near Gentle Annie Point is continued south of the Mokihinui by a much larger area that reaches to within three miles of the Ngakawau River. The gravels and sands of the coastal region north and south of Westport are almost everywhere underlain at small or moderate depths by Miocene rocks, of which various outcrops are seen near the foot of the Papahaua Range between the Waimangaroa and Buller rivers. There is also an isolated exposure near Fairdown. West and south of the Buller outcrops are seen near Bradshaw's, and more especially in the deep stream valleys near the foot of the Paparoa Range. An excellent section is exhibited by the cliffs near Cape Foulwind, whilst south of Addison's numerous and almost uninterrupted outcrops extend to the southern boundary of the subdivision. At Cape Foulwind, however, and along the coast from Charleston southwards, granite or gneiss forms the surface, the once-overlying Miocene rocks having been removed by denudation. A great development of the Oamaru Series on the eastern side of the Paparoa-Papahaua earth-block occupies practically the whole of the Inangahua *gräben;* but the only portions of this within the subdivision are the south-east part of Orikaka Survey District and the eastern part of Ohika Survey District.

In all, about 63¼ square miles are indicated on the maps as occupied by Miocene strata. To this area may be added nearly all those portions of the coastal plain shown as covered by Quaternary gravels and sands.

STRUCTURE.

The Miocene rocks of the Buller-Mokihinui Subdivision are characterized by an undulating structure, unaccompanied by any regular folding. They usually exhibit gentle

* N.Z.G.S. Bull. No. 11, 1910, pp. 16 *et seq.*

dips, but near the more important faults may assume an almost or quite vertical position. The exposures north of the Mokihinui River show very commonly a moderate dip to the north-north-east, the result of the northward pitch of the Papahaua block. Towards the Glasgow fault a gentle south-south-east dip predominates. Along the coast, near Gentle Annie and Kongahu points, involvement in the Lower Buller fault gives rise to steep dips, most of which hade towards the south-south-east.

South of the Mokihinui, in the area traversed by Brewery and other creeks, the influence of the Lower Buller fault-zone is shown by steep dips, usually to the seaward. At the head of Brewery and Patten creeks an anticlinal structure, complicated by faulting, produces a strong dip to the eastward. The patches of Oamaru rocks near Waimangaroa are similarly involved in the Lower Buller fault, and have a general westerly dip of 26° to 85°. South of Fairdown as far as the Buller River the observable dips are moderate, varying from almost nothing to 11°. Near the Lower Buller fault, however, steeper dips must prevail, but could not be detected, owing to the lack of visible stratification in the few outcrops seen.

Some of the cores from the Sergeant's Hill bore (see page 186) show dips of from 5° to 10°. Although the direction of dip is necessarily unknown, the assumption that it is to the south of east in conformity with the observed tilt of the Westport block may be made.

The numerous outcrops of Oamaru rocks in Steeples and Waitakere survey districts in general have the gentle dip to the south-south-east that results from the tilting of the Westport block in that direction. This is well seen in the cliffs east of Cape Foulwind. Probably the Miocene strata masked by the gravels of the coastal plain between Westport and Waimangaroa have a similar easterly dip. Near the Lower Buller fault various high dips, most of them westerly, may be observed.

The large area of Oamaru rocks that occupies the eastern part of Ohika Survey District and extends through Inangahua Survey District into the south-east of Orikaka is part of the Paparoa-Papahaua earth-block, which, as explained in Chapters III and IV, has on the whole an easterly tilt. The Miocene rocks, however, instead of dipping in that direction, as might be expected, as a rule have westerly dips of 10° to 45°, and even more near faults. Such dips are seen in the Buller Gorge and in the valleys of Berlin, Nada, Pensini, and New creeks. On the other hand, the limestone of the ridge forming the eastern boundary of Ohika Survey District near Berlin's Bluff shows a gentle easterly dip. The anomalous attitude of the Miocene rocks in eastern Ohika and Orikaka survey districts is due to faults (see maps and previous chapters) which have produced several sub-blocks tilted to the west. The neighbouring area of Hawk's Crag breccia, it will be remembered, has a similar structure.

GENERAL CHARACTERS.

(1.) *Lower Oamaru Beds.*

The Lower Oamaru beds may conveniently be studied near Cape Foulwind and Charleston, where they exhibit a basal conglomerate of no great thickness, followed by fresh-water grit,* sandstone,* and shale containing lenticular seams of lignite or brown coal. The total thickness near Cape Foulwind, as shown by the section exposed in the cliffs, does not exceed 150 ft., and at Charleston is probably less.

In the Buller Valley, east of Hawk's Crag, a considerable development of conglo-

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* These beds are possibly not purely fresh-water deposits. The same statement may be made concerning some of the Oamaru conglomerate in the Buller Gorge. No decided evidence of marine or semi-marine conditions has been obtained, and this note is inserted chiefly because marine strata occur below the coal at Waitahu River, near Reefton.

merate, grit, sandstone, and shale with a total thickness of perhaps 500 ft. covers several square miles. Near Hawk's Crag are one or two thin impure seams of a pitch coal, which are probably in a lower horizon than the Cape Foulwind-Charleston lignites or any of the associated beds. These seams, with the enclosing strata, would probably have been assigned to the bituminous coal-measures by the writers had it not been that at lower (and also higher) horizons there occur conglomerates containing numerous pieces of water-worn coal and carbonaceous shale. Coal pebbles may be seen in nearly every outcrop of conglomerate on the roadside from Hawk's Crag to the Blackwater, and are again observable at Stitt's Bluff. On the north bank of the Buller the conglomerates contain many pebbles of impure coal and carbonaceous shale, some of which are partly silicified. Similar rocks occur for some distance up the Blackwater, though in this locality coal is found only in small quantity. In some places carbonized fragments of wood are present, and this circumstance renders the exercise of caution necessary in accepting any individual piece of coaly matter as having been originally derived from a coal-seam.

The hard light-coloured shales visible on the roadside a quarter of a mile west of the Blackwater and also on the track some miles up that stream are more or less silicified. They were noted by McKay as having in places the general aspect of the Cobden limestone as seen at Greymouth,* but are non-calcareous, and without doubt of fresh-water origin. From Stitt's Bluff to the eastern boundary of the subdivision at Berlin's light-coloured conglomerates, in which small pebbles predominate, outcrop at intervals.

In the eastern part of the Blackwater valley, a considerable thickness of conglomerate and coarse grit is overlain by sandstone and shale with seams of brown coal. These latter beds probably correspond in horizon to the lowest beds at Cape Foulwind and Charleston.

The rocks between Hawk's Crag and Berlin's present some peculiar characters, which differentiate them from the Lower Oamaru strata as seen elsewhere in the district. In lithological characters they seem related to the Hawk's Crag breccia. This is to be explained by the assumption that they consist mainly of material which was derived from the adjoining area of the breccia, and, largely in the form of fan gravel, was deposited in a wide valley that extended towards the south-south-east from the present watershed of Stable Creek.

In the south-east part of Orikaka Survey District the Lower Oamaru beds consist of a little conglomerate, resting as a rule upon granite, followed by grit, sandstone, and shale containing lenticular seams of brown coal.

North of the Mokihinui River the strata assigned to the Lower Oamaru are mainly sandstone and mudstone, probably of estuarine character. In one or two places—for instance, Sawyer and Mumm creeks—grit and even conglomerate appear. In Podge's Creek, which flows into the Mokihinui east of Seddonville, a few water-worn pieces of coal occur in a sandy mudstone. The Lower Miocene beds of the Mokihinui district contain no brown coal or lignite, and are correlated with the fresh-water deposits seen elsewhere on account of their position some distance below the limestone horizon. Northward and westward they thin out, so that in those directions Middle and, as the overlap increases, even Upper Oamaru beds are found resting unconformably upon much more ancient rocks.

Coal Pebbles in Oamaru Beds.—The coal pebbles found in the Oamaru rocks at various horizons, but chiefly in the lowest beds, appear to the writers important evidence of unconformity between the Oamaru Series and the bituminous coal-measures.

* "Report on the Geology of the South-west Part of Nelson and the Northern Part of Westland." Mines Report, 1895, C.-13, p. 7; and p. 16 of reprint (1897).

Proximate analyses of the coaly pebbles from various localities on the west coast of the South Island are as follows:—

—	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Fixed carbon ..	40·70	35·59	39·33	45·41	41·96	17·37	61·13	23·21	29·08	54·73
Volatile matter ..	45·61	47·28	49·00	35·14	46·19	29·38	13·13	9·19	10·82	20·86
Water	7·37	5·05	8·15	9·24	8·10	4·55	0·41	0·91	0·66	7·19
Ash	6·32	12·08	3·52	10·21	3·75	48·70	25·33	66·69	59·44	17·22
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Total sulphur per cent.	..	..	0·96	0·71	1·46	0·91	0·21	0·43	0·26	0·50
Specific gravity ..	..	..	..	..	..	..	1·575	2·205	1·36*	..

* No explanation of this low specific gravity can be given, unless an error of some kind has been made. This is not probable, however, except in so far as porosity is a factor.

(1 and 2). Omotumotu Ridge, Greymouth. Samples collected by Geological Survey (probably by A. McKay in December, 1873). Analyses by W. Skey (Lab. Rep. No. 10, 1875, pp. 9–10.)

(3.) Upper part of Kaiata Creek, Greymouth. Sample collected in 1909 by J. A. Bartrum. (See also N.Z.G.S. Bull. No. 13).

(4.) Coal pebbles from sandstone just above Cobden limestone, Punakaiki River (between Barrytown and Brighton).

(5 and 6.) Podge's Creek, Mokihinui. Bright coal and impure coal.

(7–9.) Pebbles of coal and carbonaceous shale from conglomerate, east end of Blackwater Bridge, Buller Gorge Road.

(10.) Coal from small seam, north-east of Hawk's Crag.

The coals of analyses 1–5 are strikingly similar, although from three different localities. Volatile matter in four of these predominates over fixed carbon, and water averages between 7 and 8 per cent. The highly carbonaceous shale represented by analysis No. 6, though relatively high in volatile matter, comes into the same category.

The impure coal of analysis 7, and the carbonaceous shale of analyses 8 and 9, differ greatly from the preceding samples in having fixed carbon very high, with volatile matter and water relatively low. This discordance is partly explainable by weathering, due to the porous nature of the conglomerate from which the sample was taken, but it is probable that the parent coal-seams at the time of erosion were different in composition. Analysis No. 10, of coal from a small seam exposed on the roadside in the Miocene rocks north-east of Hawk's Crag, is quoted for comparison with the analyses of coaly pebbles from the Blackwater Bridge. A close resemblance is shown, but the pebbles, on the whole, have lost more volatile hydrocarbon, and are almost devoid of water.

For the information of the reader the following references to coal pebbles in coal-measures or associated strata may be cited:—

(1.) T. W. E. David: "The Geology of the Hunter River Coal-measures, New South Wales." Memoirs of the Geol. Surv. of N.S.W., Geology, No. 4, 1907, p. 30.

(2.) W. S. Gresley: "Coal Pebble in a Coal-seam." The *Geological Magazine*, Dec. v, vol. vi, 1909, pp. 157–60. Gresley gives references to British occurrences, and mentions the discovery of coal pebbles in the coal-measures of Pennsylvania and Vancouver Island.

(3.) W. Boyd Dawkins: Lecture on "The South-eastern Coalfield, the Associated Rocks, and the Buried Plateau," before the Manchester Geological and Mining Society, reported in *Colliery Guardian*, 8th November, 1912, pp. 940–41.

MANGATINI BRIDGE, BETWEEN B AND C SECTIONS, WESTPORT-STOCKTON COMPANY'S LEASE. THE DEEP NARROW GORGE OF THE MANGATINI STREAM IS BARELY OBSERVABLE.

VIEW NEAR MOUTH OF NGAKAWAU RIVER, SHOWING RAILWAY-BRIDGE, WESTPORT–STOCKTON COMPANY'S POWER-HOUSE, BINS, ETC.

Unconformity between Bituminous Coal-measures and Oamaru Series.—The presence of an unconformity on the west coast of the South Island between the bituminous coal-measures of approximate Eocene age and the Oamaru Series of Miocene age has already received some attention, and one of the present writers has discussed the question elsewhere.* His conclusions have been questioned by Marshall†, partly on the ground that no direct stratigraphical evidence of unconformity has been discovered, and partly for other reasons. Since Marshall wrote, much additional evidence favouring unconformity has been collected, and is embodied in a paper by Morgan, to which reference has already been made. Therefore it is not necessary here to traverse the same ground in its entirety, but the suggestion that the coal pebbles are the product of the contemporaneous erosion of neighbouring coal-seams, and the nature of the differential elevation assumed to have taken place will be further discussed.

It is perfectly certain that the admittedly Miocene brown-coal seams have not been the source of the coal pebbles in the Buller Gorge conglomerates, for they are at a higher horizon. Even the small seams of pitch-coal north-east of Hawk's Crag are, so far as has been ascertained, higher in the series than most (if not all) of the coal-pebble beds with which they are interbedded, and inspection in the field will soon convince most observers that these small and evidently lenticular seams are not the source of the coal pebbles. Much less can the brown-coal seams of a somewhat higher horizon be held accountable for them. Thus the underlying bituminous coal-seams, by a process of elimination, are found to be the all-but-certain source of the coaly pebbles, and all that remains to be decided is whether they were elevated and eroded in one locality whilst conformable deposition was proceeding in another. Clearly all erosion is contemporaneous with conformable deposition in some other part of the globe, and therefore some restriction of the term "contemporaneous erosion" by a clear definition is required. In the meantime it may be asked whether the term is fairly applicable to cases in which considerable areas have been elevated not hundreds but thousands of feet, and, after the removal of great masses of strata by denudation, have again subsided and received a fresh covering of marine sediments containing material derived from older beds. Such has been the course of events on the west coast of the South Island from Greymouth to Seddonville.

It is true that in Australia, Great Britain, and other countries conglomerates in Palæozoic coal-measures containing pebbles of coal have been regarded merely as proof of contemporaneous erosion and not of unconformity. But other evidence of local unconformity in the Permo-Carboniferous rocks of Australia‡ is not wanting; and in Great Britain considerable local unconformities within the Carboniferous rocks are clearly present. Geikie writes, "In north Staffordshire there appears to be no break in the conformable continuity of the coal-measures. But in the adjoining county of Shropshire, at a distance of not more than twenty-five or thirty miles to the south-west, a strong unconformability (locally known as the 'Symon fault') has been detected between the middle and upper coal-measures. The older strata have been thrown into folds, over the top of which the younger series has been laid down. Other unconformabilities have been claimed in various districts both in England and Scotland."§ Dawkins, speaking of the hidden Kent coalfield, is reported as saying, "The coarse sandstones, with pebbles of coal sometimes taking the form of a coal-conglomerate, and at others with pebbles of shale and sandstone. . . . first noted by Logan and

* P. G. Morgan, N.Z.G.S. Bull. No. 13, 1911, pp. 42, 52, 66, &c. and "Unconformities in the Stratified Rocks of the West Coast of the South Island," Trans., vol. 46, 1914, pp. 270–78.

† "New Zealand and Adjacent Islands" (reprinted from "Handbuch der regionalen Geologie"), Heidelberg, 1912, p. 68. See also Trans., vol. 43, 1911, pp. 392–93.

‡ T. W. E. David: *Op. cit.*, p. 2.

§ Arch. Geikie: "Text-book of Geology," vol. ii, 4th edition, 1903, p. 1050.

De la Bêche in South Wales and Somerset are equally well represented in Kent. In both areas there is the same evidence of a vast denudation of an older series of coal-measures. In both the lower measures had assumed their present physical characters before the deposition of the pennant; the plants had been fossilized and converted into coal, the mudbanks changed into shales and binds, and the sandbanks into sandstones, and the whole series brought within the reach of the forces of denudation, so as to allow of their fragments helping to build up the middle coal-measures. It may therefore be inferred that the interval between them is of great magnitude."*

That the pre-Miocene elevation of the bituminous coal-measures was differential may be regarded as proved by field evidence. No appreciable amount of folding can be shown as having taken place prior to the deposition of the Miocene strata, and therefore the uplift was almost certainly the result of block-faulting, probably accompanied by tilting. At present no boundaries for the faulted block or blocks can be determined, but the absence of bituminous coal-measures under the Miocene rocks at Cape Foulwind and Charleston, together with other circumstances, suggests that the western uplifted edge of a major block may have been to the seaward of these localities, and that the block itself was tilted to the east. Whether the "hypothesis of block-faulting with the restriction that the faulted block alone moved" suggested by C. A. Cotton† holds good or not cannot be stated, but the reference may be helpful to the reader, especially when considering the whole subject of block-faulting in New Zealand.

(2.) *Middle Oamaru Beds.*

The Middle Oamaru beds consist of calcareous claystone, sandstone, and grit, with limestone as the uppermost member. In most localities the lower boundary may be defined as the plane where fluviatile deposits are succeeded by marine strata, but in the Mokihinui district it becomes more or less indeterminate, the Lower Oamaru beds, as already mentioned, being there estuarine in character. The upper boundary is somewhat indefinite in point of time, for the limestone exposures vary greatly in thickness, and possibly in different parts of the subdivision are not strictly contemporaneous.

The various members are well seen in the cliffs near Cape Foulwind, where from west to east in upward order are exposed claystone with calcareous bands and concretions, a soft yellow sandstone (red where weathered), a further band of claystone, calcareous grit, and limestone. The total thickness shown by the section is over 500 ft. On the beach there is only about 15 ft. of rock sufficiently calcareous to be called limestone, but in the quarry to the south-east 50 ft. of almost pure limestone is visible, whilst boring has proved the existence of another 30 ft., below which comes ferruginous calcareous grit. Some miles southward, near Charleston, the limestone has increased in thickness to 400 ft. or more, but this gain is to a considerable extent at the expense of the underlying claystone, &c. Hence to the southern boundary of the subdivision limestone forms a prominent escarpment (cuesta type) facing the coast at an average distance of somewhat less than two miles inland.

Bores near Fairdown and Sergeant's Hill which attained depths of 1,742 ft. and 2,500 ft. so far as known failed to reach limestone, and therefore it is not certain that this member of the Middle Oamaru is present under the Upper Oamaru beds of the coastal plain north-east of Westport. At Gentle Annie Point, north of the Mokihinui River, the Middle Oamaru consists largely of highly calcareous claystone, some of which approaches an impure limestone in composition. Towards Kongahu Point much the same rock is seen,

* *Op. cit. (Colliery Guardian)*, p. 940.

† "On the Relations of the Great Marlborough Conglomerate to the Underlying Formations in the Middle Clarence Valley, New Zealand." *Journal of Geology*, vol. xxii, No. 4, May–June, 1914, pp. 346–63.

reposing almost directly upon granite, the Lower Oamaru beds, owing to overlap, being absent.

In the inland Mokihinui area arenaceous limestone of great thickness (probably 400 ft.) is a conspicuous member of the Middle Oamaru. This rock forms high cliffs near the New Inland Karamea Road, and is there underlain by marine mudstone and sandstone. Towards Corbyvale the limestone becomes argillaceous, and then resembles the rock at Gentle Annie and Kongahu points.

In the south-east part of Orikaka Survey District the Middle Oamaru rocks exposed are mainly bluish claystone and sandstone. The overlying limestone outcrops only in a few places—for example, at the bridge over the Buller near Lyell, about two miles up Pensini Creek (here just outside the subdivision), and on the ridge between Blue Duck and Slug creeks.

Analyses of the Middle Oamaru limestones and claystones will be found in Chapter VI, under the headings of "Limestones," "Clays," and "Cement Materials."

(3.) *Upper Oamaru Beds.*

The Upper Oamaru beds are well represented in the line of cliffs east of Cape Foulwind, where over 800 ft. of bluish calcareous sandy claystone or "marl" may be seen in a continuous section. This rock instantly recalls the "Blue Bottom" of Westland, to which it exactly corresponds in age and in every other respect. It contains numerous calcareous concretions, which are usually arranged in groups more or less parallel to the bedding planes. These concretions are popularly regarded as boulders, more especially when they unfortunately happen to be encountered in a borehole. The more sandy layers in addition to quartz grains and clayey matter contain a considerable amount of finely divided mica, some black-sand (titaniferous magnetite), and other minerals in very minor amount.

Blue clays similar to those near Cape Foulwind are seen at Bradshaw's, at Addison's, and in the valleys of the various streams descending from the Paparoa Range into the coastal district south of Westport. At quite a number of spots mining operations show them to be present at a very moderate depth beneath the Pleistocene gravels and sands of the coastal plain. Near the Paparoa Range a gritty character is fairly common, and this seems to indicate approach to the old shore-line. In that case one must suppose that the uplift of the Paparoa earth-block began before the close (if not before the beginning) of the Miocene. Confirmation of this hypothesis is perhaps afforded by the presence of small coal pebbles in Upper Oamaru beds, in the higher reaches of the Waitakere River (outside the subdivision).

North-east of Westport Upper Oamaru beds underlie the gravels and sands of the coastal plain at no great depth. The bores between Sergeant's Hill and Fairdown have proved a great thickness; but, with the exception of an isolated outcrop near Sergeant's Hill, exposures appear only towards the foot of the Papahaua Range. A yellow or brown sandstone, blue where unweathered, is by far the most common rock. It is well seen in the valleys of the Orowaiti River (Giles Creek), Ballarat Creek, and south-east of Waimangaroa Junction on the road to Denniston.

The Upper Miocene rocks of the considerable area near Mokihinui traversed by Brewery, Chatterbox, Patten, and Dufty creeks are almost entirely bluish sandstones, which weather yellow, and in places pass into sandy mudstone. The sandstones are generally fine-grained, but towards the base may become gritty. They appear to be of great thickness, but there is some repetition due to faulting, and an allowance ought probably to be made for the apparent thickening due to deposition advancing outward from the shore-line (as with the fore-set beds of a delta).

PALÆONTOLOGY.

Plants.

Carbonized pieces of wood are not uncommon in the Lower Oamaru conglomerates of the Buller Gorge, where, as previously mentioned, care is necessary in order to distinguish them from the coal pebbles which are abundant in the same beds. Immediately east of Berlin's, but outside the subdivision, impressions of leaves of ferns, conifers, and other plants are found in shales outcropping on the roadside. Coniferous leaves, similar to those near Berlin's, occur in shale overlaying the brown coal at Line's Whitecliffs Coal-mine. No plant-remains were collected within the subdivision, but leaf-impressions occur in the calcareous rocks near Corbyvale and Gentle Annie Point. The writers have also been informed that Mr. W. F. Worley, of Nelson, found fossil leaves at German Gully, near Westport, many years ago.

Casts of fucoid stems are common in the marine members of the Oamaru Series, and remains of calcareous algæ form a considerable proportion of nearly all the limestones. The genus represented is *Lithothamnion*, of a species differing from that found in the Fletcher Brook limestone of Eocene age.

Foraminifera.

Foraminifera are abundant in the limestones and in the more calcareous mudstones. Sections of the Cape Foulwind and other limestones show the presence of *Globigerina*, *Rotalia*, *Textularia*, and probably other genera.

Anthozoa.

A species of *Flabellum* (or allied genus) is fairly abundant in the Middle Oamaru claystone of the Cape Foulwind cliffs. Fragments of coral occur in the calcareous rocks of Gentle Annie Point.

Euechinoidea.

Poorly preserved remains of echinoids occur in the calcareous rocks of Gentle Annie Point, the Three-mile Creek (McKay, 1874), New Inland Karamea Road (near Corbyvale), &c.

Bryozoa.

Bryozoan fragments are found in all the limestones, and in places may form a notable proportion of the rock.

*Pelecypoda.**

Cucullæa ponderosa var. B. Hutton. Totara River, in Upper Oamaru horizon.

Limopsis sp. (?) Cape Foulwind cliffs, in claystone about 150 ft. above limestone horizon.

Glycymeris cordata (Hutton). East of Waimangaroa Junction, on road to Denniston, in shelly band of Upper Oamaru rocks.

Glycymeris sp. Casts of young shells, not a Recent species, in Middle Oamaru limestone, New Inland Karamea Road, near Corbyvale.

Atrina zelandica (Gray). Brewery Creek, near Mokihinui, in Upper Oamaru. This and the other fossils recorded from Brewery Creek were collected by McKay in 1874 (locality No. 44). The enclosing rocks, bluish in colour, are calcareous micaceous mudstone and sandstone. *A. zelandica* is a Recent species.

Ostrea (*Eostrea*) *wuellerstorfii* Zittel. Kongahu Point, in coarse calcareous grit; White Rock or Gentle Annie Point, collected by McKay in 1874 (locality No. 55). Horizon lower part of Middle Oamaru.

Pecten sp. Gentle Annie Point, in calcareous rock of Middle Oamaru horizon.

Pecten (*Camptonectes*, *Pseudamusium*) *huttoni* (Park). Cape Foulwind cliffs, at 20 ft. to perhaps 100 ft. above the limestone, and therefore in Upper Oamaru beds.

* All the molluscan determinations are by Mr. Henry Suter.

What is probably a young specimen was collected from impure limestone (Middle Oamaru) near the mouth of Six-mile Creek.

Pecten (Amusium) zitteli Hutton. Inland of White Rock or Gentle Annie Point. Probably Middle Oamaru, but may be from Kaiata beds. Collected by McKay in 1874 (locality No. 34).

Hinnites trailli Hutton (?). Near Gentle Annie Point. Middle Oamaru.

Lima sp. Karamea Road, near Stillwater Creek crossing, in Middle Oamaru limestone

Anomia sp. Limestone bluffs on New Inland Karamea Road, and Gentle Annie Point (?). Middle Oamaru.

Pholadomya neozelanica Hutton. Cast only. Near Lyell Bridge (one mile below Lyell) and probably in Middle Oamaru beds. This and other fossils from the same locality are supposed to have been collected by Hector in 1869 (locality No. 274).

Venericardia australis Lamarck (?) Near Lyell Bridge. Recent.

Cardium patulum Hutton (?). Near Lyell Bridge.

Protocardia (Nemocardium) pulchella (Gray) (?). Brewery Creek. Recent.

Dosinia (Dosinisca) greyi Zittel. Totara River (juvenile) and Brewery Creek, in Upper Oamaru. Recent.

Tellina eugonia Suter. Brewery Creek. Recent.

Chione stutchburyi (Gray). East of Waimangaroa Junction, on Denniston Road. Recent.

Chione meridionalis (Sowerby). Brewery Creek; east of Waimangaroa Junction, on Denniston Road; near Lyell Bridge.

Chione sp. East of Waimangaroa Junction on Denniston Road.

Cytherea (Circomphalus) sulcata (Hutton). Brewery Creek and near Lyell Bridge (?).

Cytherea sp. (or allied genus). Omanu or Back Creek, in Upper Oamaru.

Psammobia zelandica Deshayes. Brewery Creek. Recent.

Mactra chrydæa Suter. Omanu or Back Creek.

Mactra sp., near *M. chrydæa* Suter. Brewery Creek.

Zenates acinaces (Quoy and Gaimard). Brewery Creek. Recent.

Corbula caniculata Hutton. Brewery Creek.

Corbula humerosa Hutton. Brewery Creek.

Panopea worthingtoni Hutton. Near Lyell Bridge.

Scaphopoda.

Dentalium mantelli Zittel. Cape Foulwind cliffs, in Middle Oamaru rocks.

Dentalium solidum Hutton. Cape Foulwind cliffs; east of Waimangaroa Junction on Denniston Road; Brewery Creek: all in Upper Oamaru.

Gasteropoda.

Turbo, n. sp. Brewery Creek.

Trochus sp. Omanu or Back Creek.

Epitonium sp. (?). Brewery Creek.

Crepidula gregaria Sowerby. East of Waimangaroa Junction on Denniston Road (Upper Oamaru); near Lyell Bridge.

Polinices gibbosus (Hutton). East of Waimangaroa Junction on Denniston Road; Brewery Creek.

Polinices cinctus (Hutton). Brewery Creek. One specimen very large.

Polinices huttoni v. Ihering. Brewery Creek.

Polinices suturalis (Hutton). Brewery Creek.

Turritella murrayana Tate. Brewery Creek.

Struthiolaria cincta Hutton. Brewery Creek.

Galeodea senex (Hutton) (?). Brewery Creek.

Siphonalia sp., allied to *S. costata* (Hutton). Brewery Creek.

Siphonalia sp. Omanu Creek.

Fulguraria gracilis (Swainson) (?). East of Waimangaroa Junction on Denniston Road. Recent.

Olivella neozelanica Hutton. East of Waimangaroa Junction on Denniston Road.

Bathytoma haasti (Hutton) (?). Brewery Creek.

Conus (*Chelyconus*) n. sp. Brewery Creek.

Conus (*Conospira*) n. sp. Brewery Creek.

Pisces.

Carcharodon megalodon Agassiz. Cape Foulwind. Identified by J. W. Davis.*

In 1866 Hector made a small collection of fossils (locality No. 637) from points between Mokihinui River and West Wanganui (Westhaven). Though most, if not all, of these were obtained outside the subdivision, Mr. Suter's determinations may here be given for general information. The specimens identified were probably all from Miocene (*i.e.*, Oamaru) rocks, and are as follows: *Ostrea nelsoniana* Zittel; *Ostrea* (*Eostrea*) *wuellerstorfii* Zittel; *Glycymeris laticostata* (Quoy and Gaimard) (?), a Recent species; *Polinices huttoni* von Ihering.

In addition to the above *Mollusca*, *Terebratula magna* (Hamilton)† has been determined by Dr. J. A. Thomson in this collection.

Remarks.

Taken as a whole, the thirty-nine species of *Mollusca* given in the preceding list contain approximately 23 per cent. of Recent species. It will be observed, however, that only one of the *Gasteropoda* and neither of the two species of *Dentalium* are now living. Thus among the *Pelecypoda* eight species out of twenty-two, or 36 per cent., are Recent. The Middle Oamaru beds furnish twelve species, of which only one is now living, whilst the corresponding numbers for the Upper Oamaru are thirty-one and eight.

So far as percentages of Recent species can be accepted as a guide, it would appear that the Upper Oamaru beds are of Upper Miocene age. The fossils collected from the Middle Oamaru are not sufficiently numerous to form a safe basis for a final opinion, but the paucity of species common to the two sets of beds indicates that the plane of division adopted is a natural one.

Since only four of the identified species are common to both Middle and Upper Oamaru beds, the change of conditions at the end of the Middle Oamaru must have been very considerable, and it also follows that deposition of the limestone must have occupied a long period, as indeed could be predicted from its great thickness in several localities, for none of the Upper Oamaru species is known to recur in the lithologically similar beds beneath the limestone.

In two localities—Waimangaroa and Brewery Creek—the fossils were taken as a guide in determining the division of the Oamaru Series in which the Miocene beds were to be placed. At Waimangaroa the fossils as a whole have a Blue Bottom facies, and two out of the eight species certainly identified are Recent. McKay's most welcome collection from Brewery Creek contains twenty-five species, of which six, or 24 per cent., are Recent. Though the beds from which McKay collected were, so far as the writers can ascertain, considerably above the base of the Miocene rocks in that

* See "Report on the Fossil Fish Remains of New Zealand," Rep. G.S. during 1892–93, 1894, pp. 99, 116; and Trans. Roy. Dublin Soc., vol. iv, series ii, 1888.

† N.Z.G.S. Bull. No. 11, 1910, p. 18.

locality, yet the lithologically similar nature of the strata from summit to base, and the complete absence of limestone or any thick calcareous layer, compels the belief that all are above the limestone horizon of other localities.

In estimating the number of species the new but unnamed species and those doubtfully identified have been taken into account. Generic determinations standing alone have of course been neglected.

A consideration of the lists of Oamaru fossils from the Reefton Subdivision identified to date by Mr. Suter thoroughly confirms the Miocene age of the series, but shows that there is less difference between the upper and middle horizons than would be supposed from the results just discussed. The Upper Oamaru beds near Inangahua Junction and Brighton (Fox River) have yielded nineteen fossil species, of which seven, or 37 per cent., are living. The identified species from the Middle Oamaru beds of the same localities are thirty-eight in number, of which ten, or 26 per cent., are Recent. The combined number of species is fifty-five, containing sixteen living species, or 29 per cent.

Pleistocene Beds.

The Pleistocene strata of the Buller-Mokihinui Subdivision consist mainly of marine sandstone, together with morainic, fluvio-glacial, and fluviatile gravels. They pass upward into Recent deposits, from which they cannot well be entirely differentiated. From the Miocene rocks they are separated by a well-marked unconformity, easily seen, for example, in the excellent section furnished by the cliffs east of Cape Foulwind. Owing to their auriferous character, the Pleistocene deposits were formerly extensively worked for the precious metal, and are still of considerable economic importance. They will therefore be further discussed in Chapter VI.

Fluvio-glacial and Morainic Gravels.

True morainic accumulations are not certainly present within the subdivision, but confused piles of large grit and sandstone blocks that occur in several places on the Papahaua Mountains probably represent material transported by snow-slides during the Pleistocene. Deposits of this nature derived from the higher slopes are found near Coalbrookdale and Kiwi Compressor. Similar material is again seen on the higher slopes of Mount Frederick, near the head of the Waimangaroa River. On the western flank of Mount Rochfort there are accumulations of angular blocks and small ridges resembling terminal moraines. Though these last-mentioned occurrences may well be due to surface slips, yet one at least, a hillock at the foot of the slopes near Christmas Creek, has all the appearance of glacially deposited material.

Some large erratics found on the Addison flats near Wilson's Lead Road are almost certainly ice-transported, for no other explanation of their presence can be offered. With these may be compared the large boulders mentioned below as occurring in the sluicing claims at Bradshaw's. A number of large rounded granitic boulders that strew the surface of the limestone near Tauranga Bay may possibly be ice-carried, as suggested to the writers by Mr. Sydney Fry, but more probably have been derived from the Cape Foulwind granite (or gneiss) and brought to their present position by wave-action at a time when the sea was at a higher level relatively to the land than it is to-day. With these may be compared the boulder-bed of the cliffs east of the cape mentioned below under the heading of "Marine Sandstone, &c."

Fluvio-glacial gravels may be seen near the main coach-road about a mile on the Westport side of the Buller Ferry (Te Kuha), and also west of the Buller on the Loop-line Road. Similar deposits occur in the Buller Gorge immediately to the east of the Ohikanui River, and, more or less mixed with talus or pluvial deposits, at several points in the U-shaped valley of that stream.

Fluviatile Gravels.

Purely fluviatile gravels of Pleistocene age have a moderate development in the subdivision. They are found on the tops of the high-level terraces north and south of the Buller, and in the middle portions of the valleys of the Waitakere River and its tributaries. Similar deposits form a cover to older rocks in several parts of the relatively depressed area immediately west of the Glasgow fault—for instance, in the upper valleys of the Ngakawau and its tributaries. Gravel-topped terraces occur in the upper Mackley Valley, and have a considerable development on both sides of the Buller near New and Pensini creeks. Owing to their generally moderate thickness, and the impossibility of obtaining defined boundaries, the Pleistocene deposits in the areas near the Glasgow fault, with the exception of those in the Mokihinui district, are not shown by the maps. Pleistocene stream gravels form portions of the high terraces in the Ohikanui Valley, but it is not always possible to draw a distinction between these and the fluvio-glacial or pluvial deposits.

In all localities the fluviatile gravels consist of material derived almost entirely from the pre-Tertiary rocks. Thus the constituent pebbles are mainly greywacke, granite, and gneiss, with minor amounts of quartz-porphyry, hornfels, schist, and argillite.

Marine and Fluvio-marine Gravels, Sands, &c.

The high-level terraces near Westport are in part formed of fluvio-marine and marine gravels and sands, supplied chiefly by the Buller River, and then more or less sorted by the sea. This material rests on Miocene claystone and sandstone which evidently have been cut by marine action into a series of shelves corresponding more or less to the main terraces, now deeply gravel-capped. The actual surfaces of the highest terraces (500 ft. to 600 ft. above sea-level) are, as previously remarked, composed of fluviatile deposits, but between this and the underlying Miocene claystone is in places at least a layer of marine material, or possibly the stream gravels pass into fluvio-marine beds towards the seaward margin. McKay writes, "On the south side of the Buller the marine sands cap the brink of the highest terrace. . . . Black-sand deposits, evidencing the presence of the sea, are also to be met with on the higher terrace."* The same writer, discussing the matter on another occasion, favours stream-deposition for the material forming the high-level terraces north of the Buller, the reason given being that there is a scarcity of black-sand in that locality.†

Near Charleston there is a development of high-level terrace gravels and sands similar to those nearer Westport, except that these in part rest upon gneiss, and have a much stronger marine facies. They contain highly auriferous lenses or "beach-leads" abounding in black-sand.

Below the 280 ft. contour the coastal plain is almost everywhere coated by marine deposits, which in many places are highly auriferous. Much eroded Pleistocene beach deposits occur on the lower western slopes of Radcliffe Ridge towards the Mokihinui, and have supplied the gold obtained in Patten, Chatterbox, and other creeks. Small fragments of a raised beach are also seen near Gentle Annie Point at a height of perhaps 200 ft. above the sea.

A soft yellow-to-brown sandstone covers a considerable area from Cape Foulwind towards Addison's. Its colour is due to the oxidation of black-sand (titaniferous magnetite), which in places is concentrated into richly auriferous but lenticular layers. These are generally strongly cemented, and the same thing occurs with those portions

* "Geology of the South-west Part of Nelson and the Northern Part of the Westland District." C.–13, (in Mines Report), 1895, p. 8. Second edition, 1897, p. 17.

† "Gold-deposits of New Zealand," 1903 (reprinted from *Mines Record*), p. 26.

of the sandstone that contain much disseminated iron-oxide. The thickness of the sandstone as a rule does not exceed 25 ft. to 30 ft., but near Charleston a loose white quartz sand seen at the end of the Back Lead Road reaches a thickness of over 100 ft.

At the base of the Pleistocene sandstone, as exposed by the Cape Foulwind cliffs, a discontinuous layer of gneiss or granite boulders (a beach deposit) resting on the eroded Miocene rocks is visible. Above this in one or two places is a peaty lignite layer a foot or more in thickness.* A corresponding boulder bed, overlain by 10 ft. to 15 ft. of sand and shingle, above which is 10 ft. of gravel, may be seen in a sluicing claim at Bradshaw's, and in Dennehy's claim (Bull's) a carbonaceous layer probably in quite the same horizon as the Cape Foulwind peaty material is exposed. Some of the boulders are from 3 ft. to 5 ft. in diameter, the largest being at Bradshaw's. Those near Cape Foulwind may quite well be regarded as derived from the neighbouring gneiss and granite now exposed at the cape, but the Bradshaw's boulders are not so easily explained, and one must suppose them to have been transported by ice to the immediate neighbourhood.

Ancient sandhills occur in several localities south-east of Cape Foulwind at 100 ft. or more above sea-level. With these may be included the higher sandhills south of Tauranga Bay, as well as various sandy ridges or sandhills at a somewhat lower level than those first mentioned south-east of Tauranga Bay and near Fairdown, Granity, and Birchfield. These latter deposits, however, are preferably classsed as Recent.

Recent Deposits.

Under this head come the gravels and silts of the various river-flats; the unfixed sand-dunes that fringe the shore-line in most localities, except Cape Foulwind, from Charleston to Gentle Annie Point; fan gravels; pluvial deposits; talus, &c.

Talus, fan, and pluvial deposits, which may in part be regarded as Pleistocene, fringe the foot of many mountain-slopes. They are more prominent in the valley of the Ohikanui than anywhere else in the subdivision. Near Birchfield, Fan Creek has formed the prominent deposit to which it owes its name, and the Totara River has also built a considerable fan.†

Igneous Rocks.

CONTENT AND GENERAL ACCOUNT.

Igneous rocks of various types have a notable development in the subdivision. They consist chiefly of quartz- and granite-porphyries, granites, gneissoid granites, and gneisses, associated with more or less contemporaneous acid, intermediate, and basic dykes. With the possible exception of some of the gneissic rocks, these are all clearly differentiation products of the one magma. In addition, lamprophyric dykes of later age transect the granites and the Eocene breccias.

Various more or less irregular masses of intermediate composition and dioritic affinities are apparently intrusive into the granites, but seldom form true dykes with clearly defined walls. Most of them may probably be classed more accurately as segregations, and are evidently similar in this respect to the occurrences in the Mount Radiant district stated by Webb to appear "sometimes as well-defined dykes, but more frequently to have much the appearance of segregations from the main mass."‡

The quantitative chemical classification given on a later page confirms the suspicion that the lamprophyres, though of a much later date than the other dyke rocks, are

* See also Alex. McKay: "Reports Relative to Collections of Fossils made on the West Coast District, South Island." Rep. G.S. during 1873–74, No. 8, 1877, p. 107.
† McKay: *Op. cit.* (C.–13, 1895), p. 8; second edition, p. 17.
‡ N.Z.G.S. Bull. No. 11, 1910, p. 15.

also differentiation products of the one granitic magma. Before they were injected, sufficient time had elapsed to permit the exposure of a considerable area of granitoid rocks by erosion of the overlying sedimentaries, and the consolidation of the coarse material constituting the product of this denudation.

DISTRIBUTION.

The only types of igneous rock having an important areal distribution are the granites, gneisses, and quartz-porphyries. The localities in which these outcrop will best be ascertained by consulting the maps, which also show by special signs the various basic and acidic dykes located during the survey. Remarks concerning the distribution of the several types will be found in the sections specially devoted to them on later pages.

AGE AND CORRELATION.

Nothing definite is known concerning the age of the granites and associated rocks further than that they are post-Aorere and pre-Tertiary in date. Since Triassic conglomerates containing numerous pebbles of granite and other igneous rocks are well known as occurring in northern Nelson* a pre-Triassic age may tentatively be assigned to all the granitic rocks of Nelson and Westland. The lamprophyres, however, in places cut the early Tertiary breccias of the bituminous coal-measures, and are therefore post-Mesozoic in age. They are correlated by the writers with the similar rocks in North Westland described in the bulletins dealing with that area.

GRANITE AND GNEISS.

As shown by the maps, granite and gneiss are exposed over large areas in the subdivision, and moreover in many places underlie the sedimentary rocks at no great depth from the present surface. Granite outcrops extensively on the slopes of Mount Kilmarnock and the Glasgow Range, in the Mokihinui gorges, and on the western side of Mount Frederick. It is well exposed in the Buller Gorge, and forms much of the northern part of the Paparoa Range, especially within the Ohikanui and Blackwater valleys. On the western side of the range, in the watersheds of the Totara and Nile rivers, and in the central part towards the head of the Ohikanui, the granite becomes more or less gneissoid. Gneiss and gneissic granite, doubtless in continuity with the Paparoa Range granite, outcrop extensively in the Charleston district, and reappear at Cape Foulwind. The rock forming the core of Radcliffe Ridge and its virtual continuation—the seaward ridge north of the Mokihinui River—is largely gneiss. Gneissic types of rock appear in the gorge of the Ngakawau, outcrop in many places along the crest and slopes of the Mount William Range, and have an extensive development in the Mackley watershed. In addition the maps show many small and apparently isolated patches of granite or gneiss, especially in the Ngakawau Survey District, which are really inliers surrounded by bituminous coal-measure rocks. Since in mining reports granite and other igneous rocks have been frequently regarded as intrusive into the coal-measures, it may be well here to explain that, with the exception of the lamprophyric dykes intersecting the Hawk's Crag breccia, no such intrusions have taken place. The matter is again mentioned in Chapter VI.

At many places in the Mokihinui, Ngakawau, and Orikaka survey districts granite and gneiss are so intermingled that separate mapping or description becomes impossible. Whether this state of affairs is to be explained as due to an irregular production of gneissic structure in one original granite, or whether there are in the subdivision two

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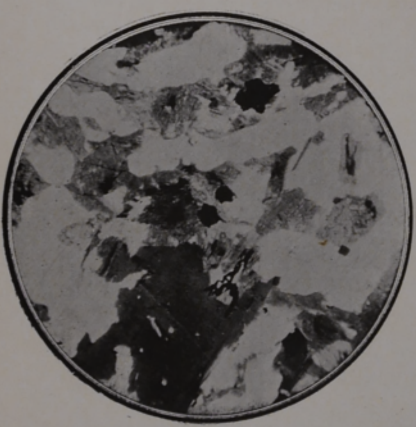
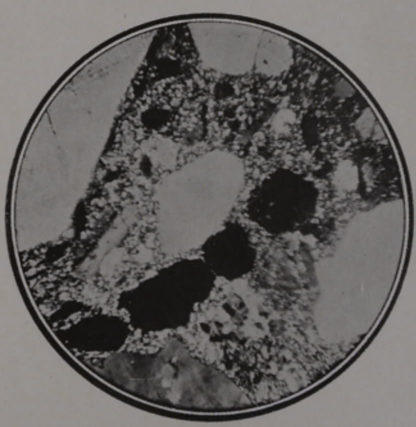
* The igneous constituents of this Triassic conglomerate have been described by Marshall in a paper entitled "Boulders in Triassic Conglomerate, Nelson," Trans., vol. xl, 1904, pp. 467–71.

1. 2.

1. Granite with Prominent Microcline, Road to Mokihinui Reefs.
2. Same Rock as 1.





3. 4.

3. Diorite from a Tributary of T 35 Creek.
4. Quartz-porphyry, Kiwi Creek.

Magnification of all Figures about 27 Diameters.

[To face page 96.

granites of different ages, the older of which was in general converted into gneiss, and was then intruded in a complex manner by the later granite, cannot be positively determined. Although the field evidence in various localities supports the latter view, yet this is not always the case, and since no essential difference in composition or other character apart from foliation has been detected, the opinion that gneiss and granite are essentially of the one age has the greater weight.

On the other hand the sediments forming the Aorere Series show by their composition that they were probably derived from an ancient land-surface of granite, gneiss, or allied rocks.* Hutton† and Park‡ make statements favouring the view that granitic rocks of two widely separated ages are present in the central and western parts of Nelson. Again, one of the present writers considers the gneissic rocks of North Westland to be decidedly older than the granites of the same region.§

QUARTZ-PORPHYRY.

Quartz-porphyry, in places with the characters of a granite-porphyry, has a fairly wide distribution in the Buller-Mokihinui Subdivision. It occurs either in large dyke-like masses penetrating the Aorere rocks, or as fringes to granite, into which it appears to pass without any sharp plane of separation. The chief localities in which quartz-porphyry has been observed are between Burnett's Face and Coalbrookdale; in the Waimangaroa River south-south-east of Denniston; in Kiwi Creek (east of Waimangaroa) in Wilson Creek (a tributary of the Upper Waimangaroa); Cascade Creek valley; Stable, Newman, and Payne (Slaty) creeks (Buller Gorge); and Mount William Creek. Various occurrences in Inangahua Survey District somewhat outside the subdivision will be described in Bulletin No. 18. The granite-porphyry phase may be seen in the valleys of Cascade and Payne creeks.

A noteworthy feature of the quartz-porphyries is that in several localities they contain small angular fragments of greywacke and argillite in such number that the appearance of a breccia is presented, more especially by the weathered rock. This is particularly the case with the rock between Burnett's Face and Coalbrookdale, which contains also a few rounded fragments of a granite with pinkish feldspar. The inclusions of sedimentary rock are more or less converted into hornfels, but otherwise are very little altered, so that one may conclude that the quartz-porphyry was neither intensely heated nor well supplied with mineralizing solutions at the time of its intrusion.

Some early observers apparently mistook the quartz-porphyry with inclusions for a sedimentary rock, and it was therefore recorded as "sandstone breccia," &c.|| Many years ago Hutton described specimens as "liparite" and "rhyolite,"¶ but rejected the name "quartz-felsite."** He, however, had not seen the rock *in situ*, having obtained one specimen from Dr. Gaze, and another from the gravels of the Buller River.

Hector apparently recognized the presence of quartz-porphyry underlying the bituminous coal-measures, for in 1872 he writes, "In some places on the West Coast this formation passes downward into a breccia of green- and blue-slate rock-fragments, cemented with quartzose porphyry."††

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* See also N.Z.G.S. Bull. No. 1, 1906, p. 46; Bull. No. 6, 1908, pp. 85, 96; &c.

† "Sketch of the Geology of New Zealand." Q.J.G.S., vol. xli, 1885, pp. 198, 215.

‡ "On the Geology of Collingwood County, Nelson." Rep. G.S. during 1888–89, No. 20, 1890, pp. 230–31.

§ P. G. Morgan: N.Z.G.S. Bull. No. 6, 1908, p. 82. See also pp. 30, 76, &c.

|| See for example Denniston's report, *op. cit*, sections 162 and 163, p. 167; and McKay, "Geology of the South-west Part of Nelson and the Northern Part of Westland," C.–13, Mines Report, 1895, p. 7, and Second Edition, 1897, p. 16, where he speaks of the "breccias of Grainger's Point."

¶ See, however, page 101, where mention of possible rhyolite in the district is made.

** Trans. of the Geol. Soc. of Australasia, vol. i, pt. 4, 1890, pp. 109–10. In Jour. and Proc. Roy. Soc. N.S.W., vol. xxii, 1889, pp. 114–15, Hutton uses the name quartz-felsite.

†† "On the Remains of a Gigantic Penguin (*Palæudyptes antarcticus* Huxley) from the Tertiary Rocks on the West Coast of Nelson." Trans. vol. iv, 1872, p. 345.

ACIDIC DYKES.

Acidic dykes, represented mainly by pegmatite, traverse the granitic rocks of the subdivision in many places. They frequently contain tourmaline and garnet in addition to the essential quartz, feldspar, and mica, but are seldom of much interest in other ways. To this statement a large pegmatite dyke near Charleston, which has been worked for its mica-content, is an exception.

The only aplite dyke noted during the course of the geological survey is outside the eastern boundary of the subdivision, and traverses schistose rocks near the junction of Hodges Creek with the Rough-and-Tumble (Mokihinui). This dyke, which presents no features of more than ordinary interest, is presumably an apophysis from the granite that outcrops in the immediate neighbourhood.

INTERMEDIATE IGNEOUS ROCKS.

The intermediate igneous rocks may be defined as having a silica percentage between 55 and 65. This definition excludes the granodiorite of the Mokihinui district, but includes many of the dioritic segregations from the granite previously mentioned as not forming well-defined dykes. These are mostly quartz-diorites showing an approach in some cases to syenite. Some examples are described on later pages.

BASIC DYKES.

The basic dykes are in part diorites without quartz, but are more especially dolerites and lamprophyres (camptonite, monchiquite). Those actually observed, with the exception of a diorite dyke in the Mackley River, were of small size, but large boulders seen in the lower Ohikanui and the upper Blackwater valleys indicate lamprophyric dykes of considerable width in those localities.

PETROGRAPHY.

I. *The Granite Series and Associated Igneous Rocks.*

The petrographical types represented in the granite series and the associated intrusives include—(1) Granites, (2) gneissose plutonic rocks and gneisses, (3) quartz-porphyry, (4) pegmatites and aplites, (5) syenites, (6) quartz-diorites and diorites, (7) dolerite.

These types, with the possible exception of the dolerite, all arise from the one magma, in which differentiation, assisted to a minor degree by differences in the rate of cooling, has been responsible for the variation in the resulting products.

The difficulties in distinguishing the numerous gradations existing between typical granites and typical gneisses prevent more than an approximation to the true relations of the two groups. The coarser varieties of these rocks are inclined to be incoherent, and thus microscopic study is hindered by the difficulty of preparing good sections. These, however, were made in moderate number, and tend to show that, with the probable exception of some coarsely banded contorted gneisses in the southern part of the Waitakere Survey District, the unaltered granites and the gneissose granites are one and the same rock. A rough banding of the granite has been induced by granulation and recrystallization consequent on the pressure that has manifested itself in extended faulting, and, as may be expected, this banding, as well as the strike-direction of the more prominent joints, are in a general way parallel to the trend of the major faults.

The quartz-porphyries, which to a large extent are probably a marginal facies of the granite, approach the granite-porphyries and also the porphyrites in their general characters. The pegmatites and aplites, as is usual with such rocks, were practically contemporaneous with the granite intrusions. In many instances granite and pegmatite dykes transect the massive granite, whilst they also invade the older sedimentaries near the margins of the main boss or bosses.

(1.) *Granites.*

As may be expected in so considerable a plutonic intrusion, several members of the granite family appear, but the general uniformity is surprising when one considers that many of the occurrences are closely associated with older sedimentaries, and thus have been exposed to the influence of assimilation.

Muscovite-biotite-granite and biotite-granite are the most widely distributed types, but biotite-hornblende and porphyritic varieties are also found. In a few of the sections examined no ferro-magnesian minerals were present, so that a resemblance to the quartz-feldspar rocks of the Wrekin district and the Malvern Hills* is shown. There are one or two rocks similar in character to the adamellites as defined by Hatch,† but these are here provisionally included with the granites. What is apparently a fine-grained modification of the prevailing granite, in the gorge of the Mokihinui River above Seddonville contains abundant plagioclase, and must be classed among the granodiorites, a decision which is justified by the chemical composition (see analysis No. 6, page 105).

In the field the granitic rocks present considerable differences in texture, and to a less extent in structure; and, as previously stated, rapid changes from a gneissose rock to typical granite frequently occur within the space of a few yards. The most common type is a moderately coarse-grained greyish rock, which usually weathers to a pinkish colour.

The structure is moderately uniform, and is typically granitic in most of the varieties other than those exhibiting a porphyritic development. Graphic intergrowths of quartz and feldspar are rarely seen. In nearly all the sections examined evidence of severe pressure is afforded by undulose extinction of the quartz and occasionally of the feldspar, and by the rupture and bending of the mica lamellæ. With an approach to gneissose structure granulation and recrystallization of the quartz give proof of more intense pressure.

The minerals most commonly identified in addition to the essential constituents are apatite, zircon, and rutile, together with secondary rutile (sagenite), chlorite, and sericite. Tourmaline, magnetite, sphene, and garnet, with secondary epidote, pyrite, and carbonates are occasionally present; in the section (W 65)‡ of the granodiorite from the Mokihinui district sphene is moderately plentiful. Deep grass-green to yellowish-green hornblende is associated with biotite in the section (W 24) made from a specimen with idiomorphic feldspars collected near the Grenadier Rocks on the coast north of the Mokihinui River. Much of the biotite—a brownish-green variety—may be derived from the amphibole.

The varieties of feldspar are most commonly orthoclase, microcline, microperthite, or cryptoperthite that may be anorthoclase, and oligoclase. Oligoclase-andesine is sometimes recognized. Micropegmatite phenocrysts in which orthoclase, or less commonly microcline or oligoclase, is intergrown with quartz are not uncommon. Microcline frequently forms large plates which enclose rounded crystals of orthoclase, plagioclase, mica, and sometimes quartz. The alkali feldspars, though less abundant than quartz, in general much outweigh the plagioclase. The characteristic alteration is to sericite with a little quartz.

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* A. Harker: "Petrology for Students," 3rd edition, 1902, p. 36.
† "Text-book of Petrology," 6th edition, 1910, p. 153, &c.
‡ The letter and number are those given to the slide in the Geological Survey collection.

The quartz very commonly has numerous inclusions of minute, slender, rutile needles, and lines of liquid inclusions. It is the most abundant constituent in a majority of the sections.

The biotite is usually a deep-brown to pale yellowish-brown intensely pleochroic variety: purple-brown and green to greenish-brown colours are often exhibited. It shows a gradual alteration to pennine, frequently accompanied by separation of rutile needles or sagenite, and occasionally of iron-oxides. Microscopic zircons showing a strong pleochroic halo are sometimes seen as inclusions in the biotite, and, where pressure has been active, the lamellæ are generally bent or broken.

Primary muscovite is much less important than biotite in the Westport granites. Sericite, as already remarked, is a common secondary mineral, produced by alteration of the feldspars, &c.

In the Westport granites tourmaline is less abundant than in those of Westland, as for example in the Lake Brunner district. Microscopic crystals are rare, and have been found only in two sections (W 2 and W 52), both representing rocks from Stony Creek, near Waimangaroa. The tourmaline in these sections is a pleochroic blue variety: whether it is primary or replaces feldspar is uncertain. Large macroscopic crystals of tourmaline are moderately plentiful in the pegmatitic rocks of several localities mentioned in a later paragraph. A pebble of a curious schorl-rock composed chiefly of deep-brown tourmaline prisms enwrapped by a small amount of quartz and feldspar was collected from the Mokininui River bed.

In one or two slides (for example, W 3, from Stony Creek) there is a moderate amount of microgranitic quartz, feldspar, and mica matrix which enwraps the coarser minerals, and gives a distinctly porphyritic aspect. In the coarsely crystalline, somewhat porphyritic granitic rock (W 10), already described by Hutton,* that outcrops on the Denniston–Waimangaroa horse-track, a pseudo-ophitic structure unusual in granites merits remark. Large plates of cryptoperthite enclose or enwrap numerous crystals of quartz, oligoclase, and mica. Quartz forms similar but smaller and less-plentiful plates. The leading minerals have a markedly idiomorphic character.

Amongst several other types from the Westport district, Hutton describes a garnetiferous muscovite-granite from the lower part of Buller Gorge.†

(2.) *Gneissose Plutonic Rocks and Gneisses.*

Gneissose granites have a wide development throughout the subdivision, and, so far as the present investigation has gone, appear to represent the effect of pressure upon the granites of the preceding section, but the reservation is made that in part they may be of older age. Gneissose dioritic rocks have also been found.

Hutton‡ and Sollas§ have described sections from such rocks at Cape Foulwind, and the latter's description is applicable in a general way to most of the similar rocks of the district. The quartz, however, seldom shows such precise granulation and definite banding of granules as that in Sollas's section (which has been examined by the writers), but more usually forms coarse poorly defined bands of material that has been partially granulated and then recrystallized.

A gneissose dioritic rock (W 12) from West Creek, near the "Nine-mile Ferry" shows abundant coarse crystals of epidote and a curious metasomatic silicification of original plagioclase indicated by the plates of replacing quartz exhibiting striations

* "Description of some Eruptive Rocks from the Neighbourhood of Westport, New Zealand." Trans. Geol. Soc. of Australasia, vol. i, pt. 4, 1890, pp. 108–9.
† "The Eruptive Rocks of New Zealand." Jour. and Proc. Roy. Soc. of N.S.W., vol. xxiii, 1889, p. 113.
‡ *Op. cit.* (Trans. Geol. Soc. of Australasia), pp. 107–8.
§ Sollas and McKay: "Rocks of Cape Colville Peninsula," vol. ii, 1906, p. 159.

that appear to be indicative of albite twinning. The epidote probably represents original hornblende, for what appears to be a basic portion of the rock in West Creek is an amphibole diorite, and contains coarse epidote as an alteration product (Section W 16). Another dioritic rock containing abundant granulated and recrystallized quartz in irregular mosaics constitutes a dyke intrusive into granite in Island Creek. Epidote occurs abundantly as almost colourless non-pleochroic crystals, some of which are granular, whilst others are sharply idiomorphic. Biotite is the only original ferro-magnesian mineral present.

Gneisses showing distinct, often contorted, bands of $\frac{1}{16}$ in. to $\frac{3}{8}$ in. thick, in which the leucocratic and melanocratic minerals are alternately segregated, outcrop in various parts of the southern portion of the subdivision, and may be seen typically developed at the mouth of the Waitakere River. These and similar occurrences possibly represent "*lit par lit*," or injection gneisses.* The banded gneisses are readily distinguished in the field from the gneissose granites, although the latter show more or less definite banding in spite of other variations in their macroscopic appearance. In all the gneissose granites biotite, feldspar, and quartz are prominent, the feldspar being often in rounded rhomb-shaped crystals, or "eyes," surrounded by a fine-grained mixture in which quartz and feldspar predominate. Pink garnets are occasionally, but not commonly, present. Frequently associated with the gneissose rocks of the Paparoa Mountains are bands locally 20 ft. in width that consist almost entirely of biotite in soft flexible scales of small dimensions, and in several instances coincide with zones of intense shearing. In most cases there is a progressive increase in the proportion of biotite from the wall-rock towards the central portion of the band. These occurrences may represent either basic dykes or segregations in the original granite. On the supposition that they were originally basic dykes it is probable that the biotite has been derived in large measure from amphibole, for several dioritic dykes in the neighbourhood illustrate this type of alteration.

(3.) *Quartz-porphyries.*

Acid intrusions broadly referable to quartz-porphyries are common in the subdivision, and vary in size from dykes a few feet in width to large masses of the nature of small laccoliths. The petrographical similarity of specimens from widely separated localities is striking. Macroscopically they often show a marked resemblance to fine-grained granites, but more usually they exhibit a dark, more or less glassy-looking matrix in which quartz and feldspar crystals of moderate size are prominent. A most characteristic and persistent feature is the occurrence of small angular inclusions of hornfels, which vary in size from microscopic fragments to zenoliths an inch or more in diameter, and may be numerous enough to give the rock the appearance of a breccia.

Hutton has variously described several sections of these rocks as quartz-felsite,† liparite, and rhyolite.‡ Possibly the last-named rock does occur in the district, for boulders of a flow rock resembling rhyolite occur in Mount William Creek.

Essentially the quartz-porphyries are highly porphyritic rocks in which coarse abundant phenocrysts of quartz, feldspar, and biotite are enwrapped by a fine-grained to cryptocrystalline groundmass of quartz, biotite, and possibly feldspar. The differences exhibited are in the texture and structure of the groundmass, in the relative proportions of the phenocrysts to the matrix and to one another, and to a less extent in the degree of idiomorphism shown by the porphyritic minerals.

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* In this connection may be cited an article by Clarence N. Fenner, "The Mode of Formation of Certain Gneisses in the Highlands of New Jersey," in the *Journal of Geology*, Nos. 6 and 7, vol. xxii, 1914, pp. 594–612, and 694–702.

† *Op. cit.* (Jour. and Proc. Roy. Soc. of N.S.W.), pp. 114, 115.

‡ *Op. cit.* (Trans. Geol. Soc. of Australasia), pp. 109, 110.

Besides the minerals already mentioned, subsidiary zircon, apatite, and iron-oxides, with secondary sericite, pyrite, quartz, chlorite, and carbonate, may also be present. In one or two sections leucoxene is abundant. Primary muscovite is practically absent. The structure of the groundmass is felsitic, micropœcilitic, microcrystalline, or finely microgranitic, and accordingly the rocks may often be termed granite-porphyries, or microgranites.

Both quartz and feldspar phenocrysts may either be much corroded or sharply idiomorphic. The quartz is extremely abundant, is frequently very coarse, and usually contains bands of liquid inclusions. The feldspars—orthoclase, oligoclase, or acid-andesine and occasional probable anorthoclase (W 35)—vary widely in their mutual proportions. The biotite is a purplish-brown variety which alters similarly to the biotite of the granites, although separation of rutile needles is much less commonly seen. Pressure is often evidenced by shadow-extinction of quartz crystals, and by broken or bent lamellæ of mica.

(4.) *Pegmatites and Aplites.*

The pegmatites of this section are coarse-grained granitic rocks occurring as dykes in the massive granites or gneisses, and less commonly in the older sedimentaries. They consist essentially of the same minerals as the granite.

Some of the pegmatites have an exceedingly coarse texture, and this is particularly the case with that of the Charleston Mica-mine, where orthoclase crystals, some sharply idiomorphic, were observed up to 1½ ft. in diameter. The mica of the pegmatites is mainly or wholly muscovite. In the Charleston mine some of the plates attain a diameter of 10 in. or more, but unfortunately the brittle and broken nature of much of the mineral detracts considerably from its commercial value. Other features of the Charleston dyke rock are the abundance and perfection of graphic intergrowths of quartz and feldspar, together with the presence of pink garnet in moderate quantity. It also contains a soft scaly micaceous mineral of a pale-greenish tint, which may be of secondary origin.

In the pegmatite boulders of Pensini Creek and the middle Mackley tributaries, Plateau and Tiger creeks, tourmaline is tolerably abundant; in the former locality garnet is also a common constituent.

Only one aplite dyke (W 68) was specially noted, and this happened to be just outside the eastern boundary of the subdivision. It outcrops on the old inland road to Karamea immediately north of Hodges Creek, and on microscopic examination was found to be an aplite-porphyry, constituted by a microgranular groundmass of quartz, cryptoperthite, and a little muscovite, containing a few large phenocrysts of cryptoperthite.

(5.) *Syenites.*

A hornblende-syenite from near the coast, 16¾ miles north of Westport, has been described by Hutton, and is stated by him to contain epidote in veins and also in the hornblende.* On account of the rarity of syenites in New Zealand this occurrence has considerable interest.

Basic boulders (W 9) from the head of Stony Creek, Waimangaroa, are similar to the rock described by Hutton. The macroscopic characters are like those of the diorites described in the next section, but quartz and orthoclase are plentiful, whilst plagioclase (andesine) is present but unimportant. Ferro-magnesian minerals—pleochroic green hornblende and biotite—constitute about one-half of the rock. The hornblende is idiomorphic and very abundant. It shows alteration either to a fibrous serpentine with plentiful carbonate, or less commonly to a fibrous amphibole resembling actinolite.†

* *Op. cit.* (Trans. Geol. Soc. of Australasia), pp. 110–11.
† See footnote on next page.

The quartz and orthoclase form large conspicuous plates completely enwrapping the ferro-magnesian and earlier minerals.

(6.) *Quartz-diorites and Diorites.*

Quartz-diorites and diorites are very commonly found as boulders in the stream-beds of the subdivision. Several irregular dykes and other larger intrusive bodies, all of a uniform petrographical character, have been found in the granites and gneissoid rocks of various localities. These are—Branch of T 35 Creek, Ngakawau Survey District; Mackley River above Mossy Creek junction; Slug Creek, a tributary of Pensini Creek; Three-mile Creek, north of Mokihinui River; New Inland Karamea Road, near the head of Stillwater Creek. As previously noted, gneissic diorites also outcrop in West and Island creeks.

The only published description of a diorite from the Westport district is Hutton's record of a biotite-hornblende type forming a dyke in granite west of the Ohikaiti bridge, Buller Gorge.* In another paper, written at an earlier date, but published later, he called the same rock a "typical tonalite."†

Macroscopically the diorites are coarse-grained dark-green rocks showing abundant amphibole. The microscope shows that the ferro-magnesian minerals—amphibole and biotite—are subsequent to the leucocratic constituents. Plagioclase is the other essential mineral, whilst quartz appears more or less abundantly in the quartz-diorites. Orthoclase may be present, but is seldom in important amount. Subsidiary minerals are apatite, sphene, iron-oxides, and zircon. Of secondary constituents, chlorite and sericite are almost universal, whilst tremolite, rutile, talc, actinolite, carbonate, iron-oxides, and epidote are occasionally present.

The deep-brown pleochroic biotite is probably in part primary, but has largely been derived from amphibole—a fact illustrated conclusively by many of the hornblende crystals which show the alteration progressing from numerous loci in each crystal, with secondary biotite flakes forming parallel to one another.

The plagioclase varies from oligoclase to acid-labradorite. The hornblende is a strongly pleochroic bluish-green or dark grass-green variety. Commonly it forms large pœcilitic plates enclosing numerous rounded crystals of feldspar and small prisms of apatite. Its usual alteration products are tremolite or talc, or chlorite with some separation of iron-oxides, whilst in a few instances a pale actinolite seems to result.‡ Sphene, well seen in sections W 83 and W 84, is there associated with iron-oxides, and may be secondary. Rutile is present with chlorite as an alteration product of biotite, and in a few sections is associated with iron-oxides.

A porphyritic hornblende-biotite rock (W 47) found in Slug Creek, though shown by chemical analysis (No. 7, page 105), to be a diorite, exhibits in section strong resemblances to the monzonites.§ Phenocrysts of feldspar, amphibole, pyrite, and occasionally biotite are recognizable in the hand-specimen, and appear in section enclosed in a moderately fine even-grained groundmass of pseudo-granular feldspar, a little quartz, and numerous small flakes of biotite. Plagioclase is present, but is subordinate to orthoclase usually present as corroded crystals. The perfect zonal structure exhibited by many of the feldspar crystals suggests the presence of soda-orthoclase. Amphibole is in long irregular prisms, and alters to epidote or chlorite.

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* *Op. cit.* (Trans. Roy. Soc. of N.S.W.), p. 128.

† *Op. cit.* (Trans. Geol. Soc. of Australasia), p. 110.

‡ Analogous alteration of hornblende to actinolite and talc has been noted by B. K. N. Wyllie and A. Scott in domitic rocks from Garabal Hill, near Loch Lomond, Scotland. "Plutonics of Garabal Hill," Geological Magazine, Dec. v, vol. x, 1913, p. 506.

§ J. A. Bartrum in "Some Intrusive Rocks from the Westport District," Trans., vol. xlvi, 1914, p. 266, describes the rock in the absence of chemical analysis as a syenite-porphyry.

An interesting rock (W 82) from the Mackley River above Mossy Creek junction resembles the other diorites in many respects, but contains abundant spongy bluish-green to pale-yellowish amphibole, considered by Dr. J. A. Thomson, who has examined the section, to be similar to the amphibole of contact-altered amphibolites in Western Australia.* The Mackley rock, it may be added, occurs as a dyke-like member of a complex of highly altered igneous and possibly sedimentary rocks. (See also page 58.) An analysis (No. 9) is given in the table on the next page.

The structural characters in the various members of the diorite series are moderately constant, and the texture is invariably coarse. The amphibole usually presents idiomorphic outlines to large enwrapping plates of quartz or feldspar. In one section (W 23) where coarse plates of hornblende enwrap rounded feldspars an excellent example of true ophitic structure is furnished.

(7.) *Dolerite.*

A dolerite of a type very different from that to be presently described, and, as judged by the description, probably related to the camptonites, has been recorded by Hutton as occurring near Lyell,† not far outside the boundary of the subdivision.

The dolerite (W 20 and W 21) noted by the writers was found as boulders amongst greywacke débris on the New Inland Karamea Road a little north of the Six-mile Creek crossing. It is a dark-green diorite-like rock showing small feldspar laths in abundance on partially weathered surfaces. It is holocrystalline, moderately coarse, and characterized by perfect ophitic structure, wherein abundant long, stout, andesine laths are enwrapped and partially enclosed by pale-violet augite, which is more or less uralitized, and is very sharply limited by the edges of the feldspar laths. Iron-ore, chiefly ilmenite, and secondary carbonates, chlorite, and biotite are abundant. The uralite alters to chlorite, with small flakes of biotite. Some of the chlorite present is a direct alteration product of augite.

II. *Lamprophyres.*

Lamprophyric rocks have been found within the Blackwater River watershed, where in the form of dykes they intrude granite and the basal breccias of the bituminous coal-measures. Considerable interest attaches to this discovery, for they are allied to similar rocks in Westland,‡ and furnish some data for determining the age of the whole lamprophyric series. So far as known these rocks do not occur in the higher beds of the Eocene coal-measures, and therefore the time of intrusion is probably confined to a comparatively brief geological period—the early Eocene.§

The types present in the Westport district are camptonite and monchiquite. Several dykes of the former were observed during the survey of the Blackwater River and its tributary Haggard Creek. Boulders of monchiquite were found in Rider Creek, a branch of Haggard Creek, whilst the same rock forms part of a dyke that occurs near the mouth of Haggard Creek, and in different portions of its outcrop varies in type from camptonite to glassy monchiquite, and may therefore be classed as a monchiquite-camptonite dyke.

The essential minerals of the lamprophyres, all sharply idiomorphic, are violet pleochroic augite (doubtless titaniferous) in great abundance, olivine in large phenocrysts, deep-brown hornblende (barkevikite), iron-ore, and a variable but in all sections small

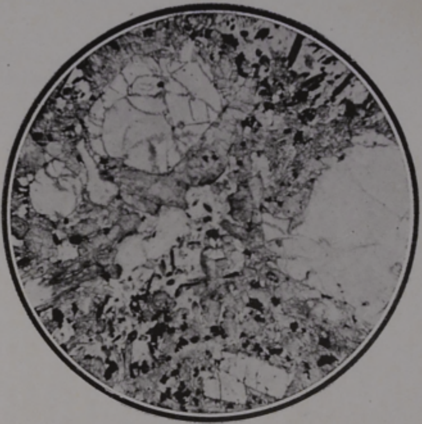
* Personal communication.

† "Note on the Geology of the Country around Lyell." Trans., vol. xxii, 1890, pp. 387–90.

‡ N.Z.G.S. Bull. No. 1, 1906, pp. 82–84; Bull. No. 6, 1908, p. 139; Bull. No. 13, 1911, pp. 80, 81. J. P. Smith: "Some Alkaline and Nepheline Rocks from Westland." Trans., vol. xl, 1908, pp. 122–37.

§ Near Blackball lamprophyric pebbles occur in a conglomerate at the base of the Brunner beds near Blackball. See N.Z.G.S. Bull. No. 13, 1911, p. 58, and also this bulletin, p .73.

1.

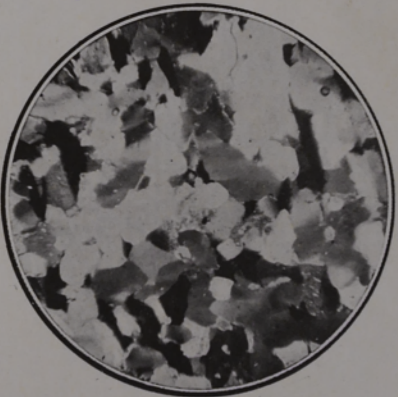


2.

1. Dolerite, New Inland Karamea Road. (See page 104.)

2. Monchiquite, Rider Creek. The Larger Light-coloured Crystals are Pilite. (See page 106.)

3.



4

3. Hour-glass Augite in Lamprophyre (Monchiquite), near Mouth of Haggard Creek.

4. Hornfels, Mokihinui District.

Magnification of all Figures about 27 Diameters.

Analyses.

—	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
SiO_2	70·36	72·85	74·75	69·40	67·90	65·65	61·25	51·65	47·70	34·50	41·80	40·37	67·08	74·87
Al_2O_3	14·30	13·79	13·77	15·27	14·77	14·27	16·53	15·07	18·41	19·50	19·00	18·60	17·87	14·14
Fe_2O_3	2·40	1·32	0·60	1·48	2·36	1·52	1·28	2·08	5·40	3·60	5·04	5·36	1·12	1·30
FeO	1·88	0·87	0·58	1·81	2·34	3·96	3·60	9·65	6·84	9·07	8·07	7·74	0·43	0·50
MnO	0·03	0·01	0·06	0·05	0·07	0·06	0·02	0·07	0·15	0·14	0·17	0·07	0·28	0·08
CaO	1·10	0·90	0·30	2·00	2·20	3·30	4·95	6·04	9·60	8·90	9·80	10·90	0·61	0·70
MgO	0·58	0·53	0·36	1·16	1·32	2·62	3·19	5·48	5·21	2·46	2·31	2·31	0·22	0·25
K_2O	5·00	5·61	4·30	3·49	3·25	4·01	2·10	0·98	0·78	1·61	1·33	1·70	9·43	2·18
Na_2O	2·59	2·77	4·51	3·39	3·33	2·22	3·71	2·57	2·58	1·59	1·79	2·95	2·34	5·06
TiO_2	0·30	0·12	Nil	0·44	0·53	0·66	0·82	3·53	0·90	3·10	3·30	3·60	0·07	0·05
P_2O_5	0·40	0·35	0·12	0·24	0·32	0·28	0·58	1·15	1·05	0·76	0·70	1·30	0·19	0·21
CO_2	Nil	Nil	Nil	Nil	0·20	Nil	0·40	Nil	0·08	9·10	0·30	3·10	Nil	Nil
Loss at 100° C.	0·33	0·10	0·23	0·15	1·39	0·12	1·82	1·85	0·20	1·62	2·50	2·09	0·07	0·04
H_2O and organic matter ..	0·88	0·95	0·17	1·10	0·10	1·18			0·82	4·22	3·97		0·97	0·40
Totals	100·15	100·17	99·75	99·98	100·08	99·85	100·25	100·12	99·72	100·17	100·08	100·09	100·76*	100·35†

* Includes—Lithia (Li_2O), trace ; sulphur-trioxide (SO_3), 0·08.

† Includes—Lithia (Li_2O), trace ; sulphur-trioxide (SO_3), 0·05 ; boron-trioxide (B_2O_3), [illegible]·52.

amount of plagioclase, which approximates to andesine. The olivine is abundant, and in the camptonite is entirely converted into iddingsite, or in some cases into carbonates, whilst in the monchiquite it is altered to pilite (tremolite and talc).

Porphyritic and non-porphyritic types are represented by the various specimens collected. The only porphyritic mineral, augite, commonly occurs in glomero-porphyritic phenocrysts, showing excellent "hour-glass" structure, or in stumpy crystals, so abundant that in some instances it constitutes almost one-half of the rock. Hornblende is solely in small, slender, cigar-shaped prisms, enclosed by the clear feldspathic groundmass or glassy base, in which indeterminate acicular crystallites occur. In one section some rounded forms of clear isotropic substance may represent a feldspathoid mineral. Iron-ore, largely magnetite, often forms phenocrysts showing an internal zone of ilmenite which has boundaries parallel to those of the periphery, and is made prominent by alteration to leucoxene.

In the monchiquite from Rider Creek gravels the only differences from the porphyritic type of camptonite are that the olivine is altered to pilite, that the brown hornblende commonly forms terminal outgrowths to the augite prisms, and that the clear base, instead of being feldspar, is a glass in which numerous crystallites appear. Green hornblende seems to be represented among these, and, after staining, minute feldspar needles may also be distinguished.

From the association of the lamprophyric rocks with granite, which, however, is of considerably earlier date, it would seem that they should be classed with the spessartites. On the other hand, the mineralogical characters agree so closely with those of camptonites as defined by Rosenbusch* that such a classification cannot reasonably be adopted.

The rocks of which analyses are given in the table on page 105 are as follows:—

(1.) Granite or gneissose granite, Cape Foulwind (W 49).
(2.) Coarse-grained granite on track to Mokihinui Reefs (W 66).
(3.) Aplite, Old Karamea Inland Road (track), (W 68).
(4.) Quartz-porphyry, Waimangaroa River.
(5.) Quartz-porphyry, with fragments of sedimentary rock, Burnett's Face (W 86).
(6.) Granodiorite on track to Mokihinui Reefs (W 65).
(7.) Diorite (near monzonite), Slug Creek (W 47).
(8.) Diorite near head of Stillwater Creek, New Karamea Inland Road (W 23).
(9.) Diorite, Mackley River above Mossy Creek junction (W 82).
(10.) Camptonite dyke in Hawk's Crag breccia, Blackwater River (W 44).
(11.) Camptonite dyke in granite, Blackwater River (W 43).
(12.) Camptonite dyke near mouth of Haggard Creek (W 41 and W 42).
(13.) Pegmatite, Charleston Mica-mine.
(14.) Pegmatite with tourmaline, Pensini Creek.

Chemical Relationships.

A study of the analyses 1 to 12 included in the preceding table shows that all the rocks fall into two main classes—one of intermediate to acid types, and the other of distinctly basic facies. In the latter of these two classes the alumina and lime percentages are high. In the camptonites, represented by analyses 10, 11, and 12, lime and alumina are probably present in important amount in the dominating highly titaniferous augite. The Mackley River diorite (analysis 9), mentioned on page 104, in the quantitative chemical classification falls into the same sub-rang as two of the camptonites. It differs mainly in its higher magnesium and much lower titanium content. This latter feature, however, is not usual in the diorites of the district, which as

* "Mikroskopische Physiographie der Massigen Gesteine," Hälfte I, 1907, pp. 684 *et seq.*

a rule contain more or less abundant sphene and minute rutile needles. Analysis 8 is representative of a rock that is considered typical of the diorites petrographically examined, whilst analysis 7 is that of a type closely approaching the monzonites in mineralogical characters (see page 103).

The diorites and camptonites as seen in the field are closely associated with the granite bosses, whilst the granodiorite exemplified by analysis 6 shows the presence of connecting links between the diorites and granites. From these facts and from the chemical characters of the series it may be safely concluded that the intermediate and basic rocks are normal in their occurrence and are differentiation products of the main granitic magma.

In the following table the norms and corresponding classifications of the igneous rocks (Analyses 1 to 12) are given, together with classification symbols in abbreviated form.*

Norms and Quantitative Classification.

Analysis.	1.	2.	3.	4.	5.	6.
Quartz	33·72	33·00	31·02	30·36	29·28	24·72
Orthoclase	29·47	33·36	25·58	20·57	19·46	23·91
Albite	22·01	23·58	38·25	28·82	28·30	18·86
Anorthite	2·78	2·50	0·55	8·06	9·17	14·46
Nepheline	..	..	..	..	..	..
Corundum	3·57	2·14	1·43	2·96	2·35	0·92
Diopside	..	..	..	..	..	..
Hypersthene	2·32	1·70	1·56	4·48	4·75	11·65
Olivine	..	..	..	..	..	..
Magnetite	3·48	1·85	0·93	2·09	3·48	2·09
Ilmenite	0·61	0·15	..	0·76	1·06	1·42
Apatite	0·93	0·62	0·31	0·62	0·62	0·62
Classification	I·3 (4)·1·3 Alaskose	I·(3) 4·1·3 Liparose	I·4·1·3 (4) Liparose	I·4·2·3 Toscanose	I·4·2·3 (4) Toscanose	II·4·3·3 Harzose

Analysis.	7.	8.	9.	10.	11.	12.
Quartz	16·02	10·56	2·34	..	2·16	..
Orthoclase	12·23	5·56	4·45	9·45	7·78	10·01
Albite	31·44	21·48	22·01	8·91	15·12	15·72
Anorthite	20·85	22·80	35·58	40·03	39·75	32·25
Nepheline	..	..	..	2·56	..	5·11
Corundum	0·51	1·53	0·20	0·41	..	..
Diopside	..	..	4·51	..	3·90	11·09
Hypersthene	12·22	24·00	17·67	..	9·42	..
Olivine	..	..	..	11·10	..	3·25
Magnetite	1·85	3·02	7·89	5·10	7·19	7·66
Ilmenite	1·52	6·69	1·67	5·93	6·23	6·85
Apatite	1·24	2·48	2·17	1·55	1·55	2·79
Classification	II·4·3·4 Tonalose	II(III)·4·3(4)·4 Tonalose	II·5·4·4–5 Hessose	II·5·4·3 (4) (Unnamed)	II·5·4·4–5 Hessose	II·5·(3)4·4–5 Hessose

The granites from Cape Foulwind and Mokihinui (Nos. 1 and 2), although falling into different orders in the classification, are closely related. Similarly the camptonite from Blackwater River (No. 10) would probably accord in sub-rang with the other camptonites were it not for the noteworthy alteration of the sample analysed

* The reader will find examples of the use of full symbols in J. P. Iddings, "Igneous Rocks," vol. ii, 1913, and in papers by other originators of the quantitative classification—*e.g.*, H. S. Washington, "Some Lavas of Monte Arci, Sardinia" (Am. Jour. Sci.—Fourth Series, vol. xxxvi, No. 216, Dec., 1913, pp. 579–590) and "The Volcanoes and Rocks of Pantelleria" (Journal of Geology, vol. xxi, 1913, pp. 653–70, 683–713, and vol. xxii, 1914, pp. 16–27).

CHAPTER VI.

ECONOMIC GEOLOGY.

INTRODUCTION.

ON the following pages the mineral resources of the Buller-Mokihinui Subdivision will be described as fully as circumstances permit. To some extent desirable data could not be obtained, either because records were wanting, as in connection with the alluvial gold-mines, or because the time available to the authors and considerations of expense did not always permit them to make an exhaustive search, as, for example, in the remoter portions of the district. The subdivision contains various materials, such as clay and building-stone, which are not of any great value at the present time, but may become very important in the future. These, together with the auriferous quartz veins, alluvial-gold deposits, and other mineral occurrences, will be given as much attention as their present consequence demands, but the greater part of this chapter will naturally be devoted to the pre-eminent mineral asset of the district—namely, its coal.

METALLIFEROUS QUARTZ VEINS.

In most localities where Aorere greywackes and argillites (the "slates" of the miner) outcrop, quartz veins, usually of no great thickness, and almost invariably of a lenticular character, are fairly numerous. The quartz, except for a moderate amount of staining by oxides of iron, generally shows slight evidence of the presence of metallic minerals. On close inspection a little pyrite and occasionally other sulphides may be seen. Gold is the only constituent of economic importance hitherto found, but is not invariably present, for in many cases it cannot be detected by panning tests, or even by careful fire assay, and, though richly auriferous patches have been found, and good returns obtained for a time, no really profitable mine has been developed in the subdivision.

The quartz veins are nearly all bedded deposits—that is, they strike and dip with the country, which usually consists of fine-grained greywacke and argillite, the coarser-grained rocks being apparently not favourable for lode-formation.

The best-known lodes occur in the watershed of Stony Creek, near Waimangaroa, where the Great Republic and Britannia companies at one time worked various lenticular but in places rich veins.* The lode mined by the former company between 1882 and 1885 varied in thickness from 3 ft. at the north end to 7 ft. at the south. On the north side of the Britannia Creek, according to an old report, it dipped westward at 45°, and on the south side eastward at a similar inclination.† The country was very loose and broken. Ultimately the lode became unprofitable, but another was found, and worked for a short time with fairly good results, though it appears to have been very loose and rubbly. The Britannia Company worked a number of lenticular veins, which were rich, but too small to enable large profits to be made. They were as a rule from 6 in. to 3 ft. wide, though in 1901 a body of stone 4 ft. to 5 ft. thick was discovered.‡ The Britannia veins are said to have had in general a flat dip, or, rather, to have consisted of a succession of flat lenticular bodies, joined by steeply dipping threads of quartz.§ The quartz in these lenses was in all cases broken into comparatively small pieces. It is now impossible to investigate the structural conditions of the Stony Creek lodes; but from the description given by H. A. Gordon it would seem that the lenses of ore were separated by faults more or less contemporaneous with the period of ore-formation. There is no record of any mineral other than gold in the quartz, but from a reference to concentrates in

* See also Chapter II.
† Mines Report, C.-4c, 1886, p. 13. (Report by Mr. G. J. Binns, Inspector of Mines.)
‡ Mines Report, C.-3, 1902, p. 53.
§ See account by H. A. Gordon in Mines Report, C.-3, 1898, p. 90.

the Mines Report of 1907, page 26, it may be inferred that pyrite and possibly other sulphides were present.

The country in which the Great Republic and Britannia veins are situated is fine-grained greywacke and argillite of greenish to bluish tints, for the most part much crushed and faulted. It is underlain, perhaps at no great depth, by granite, a mass of which outcrops to the northward of Britannia Creek, and, as will be seen on inspecting the map of Kawatiri Survey District, is traversed by apophyses and dykes of granite and quartz-porphyry, one of which was encountered in No. 6 level of the Britannia Mine, and apparently cut off the lode being worked.*

In the Waimangaroa Gorge, not far above Conn's Creek, and about three-quarters of a mile north-west of Denniston, is the Beaconsfield reef, mentioned in Chapter II. The lode is stated to be from 1 ft. to 4 ft. wide, to cross the country (greywacke of fine to medium grain) at an angle, and to have well-defined walls. The quartz, as judged from broken material lying near the old battery, is somewhat glassy, and contains a small quantity of some chloritic mineral.

Not quite a mile south of Denniston a small lenticular vein is exposed in an outcrop of fine-grained greywacke surrounded on all sides by coal-measure grit. As stated in Chapter II, this locality was prospected in 1887 and 1888 by the Denniston Quartz-mining Company, which found several auriferous leaders carrying pyrite, but no lode of any size. The shaft passes through a few feet of grit and then enters greywacke, but, being nearly full of water, cannot be descended. The tip shows some vitreous quartz, iron-stained on the joint surfaces.

In Cascade Creek valley are several quartz veins, which were prospected for gold about 1897 and at other times with unfavourable results. The only working seen by members of the Geological Survey party is a drift on the west side of the stream nearly a mile and a half below V 37 Creek junction at a point where the elevation above sea-level is a little over 500 ft. The country consists of greywacke and hornfels, but quartz-porphyry and granite are to be found not far to the west.

Near Burnett's Face a bedded quartz vein outcrops in a most accessible position on the side of the road to Kiwi Compressor, but has not been tested by driving, probably because panning tests have not given any promise of profitable results. The enclosing rock is a greenish argillite ("slate") striking about 260°, and dipping at 35° to 45° to the east of north.

In Stevenson Creek, a tributary of the Mackley, which has its sources near Cedar Creek Saddle, are several well-defined veins of white vitreous quartz from less than 1 ft. to 2 ft. in width. Two of these, about three-quarters of a mile from the mouth of the creek, apparently cross the bedding-planes of the enclosing greywacke. They strike 247°, and dip at 85° to the east of south. In addition one or two small irregular veins and lenses outcrop in the creek-bed not far away. A sample of the largest vein (2 ft.) when assayed was found to contain no gold. Three bands of quartz towards the head of the creek are probably bedded, and strike nearly east and west.

In the valley of New Creek, just outside the south-eastern boundary of Orikaka Survey District, are several quartz lodes from 18 in. to 10 ft. wide, some of which were discovered and prospected over thirty years ago. The Victory lode, the most promising of these occurrences, is outside the area mapped, and was not visited by either of the writers. It is reported to yield good assays, but to be small, and in very hard country.† The somewhat rare mineral löllingite‡ occurs sparingly as

* Mines Report, C.-3, 1907, p 26, and 1908, p. 24.
† Mines Report, C.-2, 1912, p. 26.
‡ Identified by the Dominion Laboratory.

small nests of very slender needles in the quartz. In Tichborne Creek the country enclosing the lodes tested by the Victor Emmanuel and Tichborne companies consists of hornfels and knotted schist traversed by granitic dykes. The hornfels and schist are considered by the writers to belong to the Aorere Series, and have been so mapped. They are doubtless continuous with the similar auriferous rocks nearer Lyell, which McKay* regards as "schistose rocks of unknown age" (possibly Silurian), whilst Hutton considers them to be Maitai rocks of probable Carboniferous age,† and Finlayson‡ correlates them with the auriferous rocks at Reefton. Park§ accordingly places them in the Wangapeka Series, of Silurian age. Further remarks bearing on the questions of correlation and age will be found in Chapter V, on page 68.

In Chapter II (page 29) reference was made to the auriferous veins at Seatonville (Mokihinui Reefs), some miles outside the subdivision. The ore-bodies here are for the most part small lenticular veins conforming to the bedding or foliation of the country,‖ which is probably schistose greywacke or hornfels, and in places is very hard. The Swastika Gold-mines (Limited) is now developing several small veins, and, in addition, a comparatively large body of quartz, which had been neglected in previous years.

The Inspector of Mines (Mr. T. O. Bishop) in his report for 1912 thus refers to the Swastika property: "On the steep hillside south of the Mokihinui River there are several small leaders in hard greywacke country which have been worked intermittently for many years, and have proved just about good enough to keep a working-party of men. About 100 ft. lower down the hill, and probably connected with these leaders, there is an outcrop of quartz about 20 ft. wide and 30 ft. deep—hard, glassy, bluish quartz. A sample of quartz carefully taken by me right across the face of the drive on the big reef on the 10th March, 1913, and representing a width of 5 ft., assayed 1 dwt. 8·4 gr. (value, 5s. 2½d.) gold per ton. If the large outcrop was traced down the hill and opened out at two levels—say, 100 ft. and 200 ft. below the present drive on the cap—its value or otherwise could be easily and cheaply proved."**

The rocks enclosing the Mokihinui lodes seem to be continuous with the similar rocks of the Lyell-New Creek district. They doubtless belong to the same rock-series, and are therefore of the same geological age.

In the gneissic and granitic rocks of the subdivision there are a few small veins, none of which are known to have any metalliferous content of economic value. It is decidedly disappointing to find that tin, molybdenum, and other metals commonly associated with granitic rocks, so far as known are either absent or present only in small quantities of no commercial importance.

In addition to gold, copper, lead, antimony, and possibly tin, have been reported from lodes in the Buller-Mokihinui Subdivision. References to these occurrences will be found in the list of minerals at the end of this bulletin.

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* On the Geology of the Reefton District, Inangahua County." G.S. Rep. during 1882, No. 15, 1883, pp. 101, 102.

† "On the Granites and Associated Rocks of the Upper Buller River, New Zealand." Trans. Geol. Soc. of Australasia, vol. i, pt. iv, 1890, p 100. See also "Notes on the Geology of the Country about Lyell." Trans., vol. xxiii, 1890, pp. 387–90.

‡ "The Geology of the Reefton Gold-veins." Trans., vol. xli, 1909, p. 89.

§ "The Geology of New Zealand," 1910, pp. 29, 371.

‖ H. A. Gordon: Mines Report, C.–5, 1888, p. 35.

** Mines Report, C.–2, 1913, p. 27.

Origin of Metalliferous Quartz Veins.

The quartz veins of the subdivision and adjoining areas were probably formed by hydro-thermal agencies succeeding the post-Ordovician granite and quartz-porphyry intrusions. It is somewhat surprising that the Westport district, containing as it does considerable areas of ancient sedimentary rocks intruded by igneous rocks, should not be more richly metalliferous than is the case. A possible explanation of the scarcity of profitable auriferous veins is connected with the fact that the Aorere rocks now form a comparatively thin coat on underlying plutonic rocks. This, as well as other circumstances, points to the removal by erosion of a great thickness of the ancient sedimentaries. Thus the upper and probably richer parts of the veins have been destroyed, and their gold-content scattered far and wide, part, however, to be recovered from alluvial deposits. It need hardly be pointed out, moreover, that the auriferous rocks have been entirely removed from large areas by the denuding agencies of past periods. Such areas, being either anticlinal or consisting largely of the softer finer-grained greywackes and argillites, not improbably carried more and richer lodes than those that have not been eroded to so great an extent. The small but rich veins of Stony Creek give some indication of the lost possibilities.

The scarcity of basic igneous rocks, which, found only as dykes in the granitic rocks and in the Hawk's Crag breccia, are not known to penetrate Aorere rocks anywhere in the subdivision, may also explain to some extent the comparative poverty of the quartz veins in such metals as gold, silver, and copper.

It is evident that the apparently unfavourable conditions for metalliferous deposits prevailing over the greater part of the area under consideration do not necessarily apply to adjoining areas—for example, Mokihinui Reefs and Lyell. These districts must be individually investigated before conclusions are drawn either to their advantage or their disadvantage.

Prospecting for Metalliferous Lodes.

Notwithstanding all that has been said, the Aorere rocks ("slates"), in consideration of their gold-bearing character, wherever they occur ought to be carefully prospected for auriferous quartz lodes. It should be noted that, except where they are cut off by granite or quartz-porphyry, the Aorere greywackes and argillites are continuous beneath younger sedimentary rocks. Thus they will be found at very moderate depths beneath the coal-measures from Denniston towards Mount William, and thence northwards towards and even beyond the headwaters of the Waimangaroa. It is highly probable that if the coal-measures could be removed from this area auriferous veins would be exposed.

In view of the occurrences of stream-tin in the district it is possible that careful prospecting in the Mackley watershed would reveal lodes carrying tinstone. It must be confessed, however, that the prospect of a profitable tin-mine being found is but small. Still less does there seem any hope that workable deposits of other metals such as copper, antimony, or lead will be discovered.

AURIFEROUS ALLUVIAL DEPOSITS.

I. EARLY TERTIARY (COAL-MEASURE) CONGLOMERATES AND BRECCIAS.

The basal conglomerates of the coal-measures in the Greymouth district are known to carry traces of gold,* and similar rocks in the Buller-Mokihinui Subdivision also contain a little gold, but nowhere, so far as known, in payable quantity. A small amount of gold won in the Blackwater River a mile or two above its junc-

* N.Z. G.S. Bull. No. 13, 1911, pp. 86–87.

tion is believed to have its source in the Hawk's Crag breccia, which has so extensive a development in the district. Prospectors, however, did not find any auriferous horizon in this breccia nor yet any profitable modern alluvial deposit derived from it. In passing, reference may be made to the auriferous cement of Lanky's Gully, near Reefton, which is a basal conglomerate in the Oamaru (Miocene) Series, as a Tertiary deposit probably workable at a profit. In the breccia that occurs at the mouth of the Fox River, some miles south of the southern boundary of the subdivision, a little gold is said to be present, and McKay states that the breccias found on the western side of the Grey Valley are gold-bearing to some extent.*

II. PLEISTOCENE ALLUVIAL DEPOSITS.

All alluvial deposits in the subdivision other than those forming part of the recent coastal and flood plains are here included under the heading of "Pleistocene Alluvial Deposits." Probably the range of age is moderately extensive, and in fact some of the higher raised terraces are considered by McKay to extend back as far as Newer Pliocene.†

The Pleistocene deposits may be classified as—

(*a*.) Morainic and fluvio-glacial material.
(*b*.) Fluviatile gravels and sands (including semi-residual gravels).
(*c*.) Marine gravels and sands (raised beaches).

(a.) Morainic and Fluvio-glacial Material.

There is very little glacial or fluvio-glacial material in the subdivision, and none of it is known to carry more than traces of gold. There is, therefore, nothing in the Westport district corresponding to the rich alluvial deposits of the Kumara and other goldfields in North Westland, which were formed at or near the edge of a piedmont ice-sheet. That, however, a large glacier formerly deployed on the lowlands at the foot of the Paparoa Range near Addison's is shown by the numerous large erratic boulders distributed over the coastal plain, and especially prominent in the old gold-workings. The rewash of the glacial gravels may have furnished a considerable part of the gold found in the older fluviatile gravels and raised beaches of the district.

(b.) Fluviatile Gravels and Sands (including Semi-residual Gravels).

The masses of gravel forming thick caps to the prominent high-level terraces of the Westport-Charleston district are considered to be largely of fluviatile origin, but this statement does not apply to the lower terraces. The most persistent and extensive of the high-level terraces, both north and south of the Buller River, have altitudes that vary between 450 ft. and 600 ft., and may be called the "500 ft." terraces. With these may be included a series of gravel-capped terraces rising to about the same height and equally flat-topped, which occupy a large area inland of the prominent limestone ridge to the south of the Little Totara River.

Gold is present in small amount throughout the whole of the high-level terrace gravels, and where there is local enrichment sluicing operations have been conducted. Thus deep gravels have been extensively worked on the "500 ft." terraces from the eastern or right bank of the Buller to their point of coalescence with the slopes of

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* "Gold-deposits of New Zealand" (reprinted from *New Zealand Mines Record*), 1903, p. 35.
† "Geology of the South-west Part of Nelson and the Northern Part of the Westland District." Mines Report, C.-13, 1895, pp. 19 *et seq.* Second edition, 1897, pp. 44 *et seq.*

Mount Rochfort near Fairdown, particularly near the head of German Gully, and again to the southward at McCann's claim near Addison's. Were it not for the great expense of bringing in a sufficient supply of high-pressure water, the working of the high-level gravels on a more extensive scale would, without much doubt, prove a profitable undertaking.

According to McKay,* in the gravels of the high-level terraces to the east of Addison's Flat black-sand leads are present, and thus a sea-beach origin for the basal portion of the gravel is indicated. The same feature is probably also present in the "500 ft." terraces north of the Buller. Of this, however, the writers have no proof, since no sluicing of any consequence has been done on these terraces for some years, and no indication of the existence of black-sand layers is at present visible.

Much of the high-level terrace gravel was apparently deposited near sea-level by streams from the neighbouring inland range; another portion, as already indicated, represents the rewash of earlier fluvio-glacial deposits. It is probable that several particularly rich shallow diggings near the Four-mile and Six-mile creeks south of Charleston represent local fluviatile rewash and concentration of earlier marine material.

Inland but little auriferous material falls under the heading of Pleistocene fluviatile gravels. At Grainger's Point, in the Buller Gorge, half or three-quarters of a mile east of Berlin's, and thus somewhat outside the subdivision, the gravel worked a number of years ago was at a moderate height above the Buller River, and therefore may be regarded as of Pleistocene age.† With this may perhaps be grouped the terrace gravel between Frenchman and Cockney creeks, west of Berlin's.

(c.) Marine Gravels and Sands (Raised Beaches).

The marine gravels and sands of the coastal region, particularly south of the Buller, have yielded an enormous amount of gold. As inferred above, it is probable that the auriferous wash of German Gully and the Fairdown terraces also comes under this category, and, if so, all the alluvial deposits of the coastal region worth mention are of marine origin. The chief localities where marine deposits of Pleistocene age have been worked are—North and south of Four-mile Creek; Charleston and vicinity, including Candlelight, Back Terrace, and Brown's Terrace; Croninville; Addison's and vicinity, including Virgin Flat and Wilson's Lead; Bradshaw's; German Gully; Fairdown; and Whareatea Creek. In addition some attempt has been made to work a marine deposit containing black-sand and shells which occurs on a spur north of the Waimangaroa, whilst the alluvial gold of Dufty, Patten, and Chatterbox creeks, between Nikau and the Mokihinui, seems to be derived from an ancient beach.

The bulk of the gold is concentrated in black-sand leads, and the remainder is distributed more or less patchily through the accompanying material, which consists of beach shingle, mixed with a varying amount of sea-sand. The shingle-contents are mainly grey granite and greywacke, the former rock predominating. The overlying river gravel, if present, is barren, or almost so, unless it happens to be a rewash of marine material. Where, as near Charleston, the black-sand layers are overlain by marine material only, the cover does not usually exceed 10 ft. to 15 ft. The shallowest ground is very often the richest. At Brown's Terrace, Croninville, Addison's Flat, Wilson's Lead, Bradshaw's, and German Gully there are layers of

* *Op. cit.*, pp. 8, 23. Second edition, 1897, pp. 17, 52.
† McKay, *op. cit.*, p. 16. Second edition, 1897, p. 36.

black-sand covered by from 20 ft. to 70 ft. or more of poorly auriferous gravels and sands.

The black-sand layers lie on or in a series of terraces, rising to a height of nearly 600 ft. Of these, at least six have been worked for gold near Charleston. The leads themselves are more or less discontinuous—that is, lenticular—and have a linear arrangement parallel to the ancient shore-lines, which again were approximately parallel to the present coast. At Addison's Flat the main lead is that on which the present sluicing companies—the Shamrock, McKnight and party, and Carmody and party—are at work. It is close to the base of the "500 ft." terrace, and has a southerly extension to Croninville, whilst seaward of it at least three other lines of black-sand leads have been discovered, the chief of which are Wilson's and Bradshaw's. The Addison's Flat lead is really a complex system of black-sand lenses, &c. It has been described by Gordon and McKay.*

Concentrates from sluicing claims near Addison's have been analysed by the Dominion Laboratory, with the following results:—

	1. Per Cent.	2. Per Cent.	3. Per Cent.
Silica (SiO_2)	24·77	40·40	..
Alumina (Al_2O_3)	..	12·85	..
Ferric oxide (Fe_2O_3)	30·96†	3·60	..
Ferrous oxide (FeO)		18·50	..
Titanium-dioxide (TiO_2)	29·63	13·50	..
Lime (CaO)	2·01	3·10	..
Magnesia (MgO)	0·70	0·85	..
Chromic oxide (Cr_2O_3)	0·34	Nil	0·67
Zirconium-dioxide (ZrO_2)	10·90	4·60	16·00
Rare earths other than zirconia	0·44	0·20	1·50
Alkalies and undetermined	..	2·40	..
Total	99·75	100·00	..

1. Concentrate from McCann's sluicing claim. No platinum, tin, or tungsten was detected.

2. Concentrate (black-sand) from the Shamrock Claim (new workings). The sample also contained: Platinum, 1 dwt. 21 gr. per ton; gold, 1 oz. 5 dwt. 20 gr. per ton. No tin or tungsten could be detected. The sample contained a considerable amount of iron-alumina garnet (almandine).

3. Concentrate from the plush tables, Shamrock Claim. No tin or tungsten could be detected.

Wilson's lead extends northward from Wilson's Lead Road for about a mile and a half, and has been almost continuously worked for this distance. It lies along the base of a low terrace. At the northern end the old workings show 10 ft. of soft marine sandstone, resting on 10 ft. or more of shingly gravel (with sand), which again lies on Miocene claystone (Blue Bottom). Not much black-sand is visible here, but towards the southern end of the lead the upper 15 ft. consists of gravel and sand, with cemented but not continuous layers of black-sand. There is a short lead of about 70 chains westward of Wilson's lead, indicated by old workings and a cement-battery, concerning which nothing of importance has been ascertained. Like Wilson's lead, it lies at the foot of a low terrace. Virgin Flat lead is about two miles south-west of the worked part of Wilson's, and is either a continuation of it or a contemporaneous deposit.

* "Mining Reserves, Westland and Nelson." Mines Report, C.-9, 1896, p. 8.
† Iron-oxide calculated as ferrous oxide (FeO).

Bradshaw's lead extends from some distance east of the little township of Bradshaw's to Bull's, a total distance of over two miles. It is not now continuous, being cut away east of the township by Bradshaw Creek, and to the west of the township is crossed at a very acute angle by a tributary of Bradshaw Creek, which has eroded a somewhat wide valley and removed a good deal of the lead. As a matter of fact, portions of the lead are apparently unprofitable, and have not been worked. Unlike Wilson's and Addison's leads, Bradshaw's lead is on the top of a terrace, the surface of which at the eastern extremity is about 90 ft. (or less) above sea-level. At the old workings only brown cemented sand, underlain by gravel, can now be seen. The claim near the township shows below the soil 10 ft. of gravel underlain by 10 ft. to 15 ft. of material in which sand predominates. Granite boulders 4 ft. to 5 ft., and in old workings to the east even 10 ft., in diameter may be seen resting on the bottom (Miocene claystone). To the south-westward of the township an old battery and the faces exposed in some old workings attest the presence of cemented auriferous black-sand, which seems to have formed a small lens in the Pleistocene sandstone extending over a large area in this neighbourhood. At Dennehy's claim, near Bull's, which may be regarded as on a continuation of Bradshaw's lead, the face being sluiced in November, 1912, showed 6 ft. of surface soil and clay, underlain by 10 ft. of grey sand with a few pebbles. The latter contained small lenses of black-sand, which, concentrated on a shovel till nearly all the black-sand was removed and the residue was a gray zirconiferous sand, gave an excellent prospect of fine gold. The concentrated material on analysis yielded 10 oz. 7 dwt. 22 gr. of gold and 1 oz. 14 dwt. of silver per ton. It also contained: Zirconia (ZrO_2), 10·68 per cent.; thoria (ThO_2) 0·49 per cent.; other rare earths (mainly ceria), 1·63 per cent. No platinum, wolfram, or tin was detected. The concentrate from the blanket tables (kindly supplied by Mr. Dennehy), after removal of gold by amalgamation, assayed 6 dwt. 7 gr. gold and 1 dwt. 4 gr. silver per ton. It also contained: Zirconia (ZrO_2), 2·55 per cent.; thoria (ThO_2), 0·09 per cent.; other rare earths (mainly ceria), 0·22 per cent.; chromic oxide (CrO_3), 0·50 per cent.; iron-oxide (Fe_2O_3), 29·76 per cent.; titanic oxide (TiO_2), 26·32 per cent. No platinum, wolfram, or tin could be found.

The presence of zircon, monazite, and chromite in these concentrates is noteworthy. Monazite in the Bradshaw's district was first detected by Mr. Sydney Fry, formerly Director of the Westport School of Mines. The presence of chromite here and at Fairdown was ascertained in the Dominion Laboratory.

Very little information is available concerning the auriferous marine deposits at Fairdown and Whareatea River. The old workings at Fairdown show that the greater part of the material sluiced was stream-gravel, largely derived from the slopes of Mount Rochfort, and therefore practically a fan deposit. Between this and the yellow Miocene sandstone which forms the bedrock there is, in some places at least, a layer of marine material. In this connection Mr. G. Wilson states that in the Fairdown Claim, situated at Christmas Terrace, the material sluiced consisted of 15 ft. to 30 ft. of marine sand and shingle, with varying proportions of magnetic and titanic sand, gem-sand, &c. The beach deposits were covered by an overburden varying in depth from 20 ft. to 60 ft. of subangular coal-grit, sand, and boulders.* A sample of Fairdown concentrate obtained from an old alluvial miner (per Mr. * J. M. Cadigan) consisted largely of black-sand (mainly ilmenite). This was divided by panning into two portions, of which the relative weights were not taken, but the

* Mines Report, C.-3, 1899, p. 107.

* Jim Cadigan
Govt Prospector.

heavier portion was about one-tenth of the whole. These on being analysed gave the following interesting results:—

	(1.) Heavier Concentrate.	(2.) Lighter Concentrate.
Gold per ton	1 oz. 15 dwt. 14 gr.	0 oz. 1 dwt. 13 gr.
Silver per ton	0 oz. 6 dwt. 7 gr.	0 oz. 0 dwt. 7 gr.
Value per ton	£7 2s. 11d.	£0 6s. 2d.
Platinum per ton	0 oz. 15 dwt. 17 gr.	0 oz. 0 dwt. 18 gr.
Zirconia (ZrO_2)	0·09 per cent.	0·03 per cent.
Iron-oxide (Fe_2O_3) ..	46·24 per cent.	34·56 per cent.
Titanic oxide (TiO_2) ..	23·54 per cent.	13·31 per cent.
Chromic oxide (Cr_2O_3) ..	4·00 per cent. (approximate).	3·00 per cent. (approximate).

No tungsten, tin, or rare earths could be found in the samples.

As previously mentioned, a very common feature of the black-sands exposed over considerable areas in the Charleston, Addison's Flat, and other districts is the firm cementing that has resulted from a further oxidation accompanied by partial hydration of the original titaniferous magnetite or ilmenite. In consequence the material has assumed a brown colour, though on crushing and panning off more or less black-sand will be obtained. The gold is in part visibly coated with oxide of iron, and even when no coating is visible either refuses to amalgamate or does so with difficulty. Such gold, known as "rusty gold," is supposed to be covered by a film of iron-hydroxide, which prevents contact of mercury with the gold, but it is not certain that this explanation of its refusal to amalgamate is correct.* Cementation to any great extent was not observed in the deeper black-sand leads.

III. RECENT DEPOSITS.

The deposits classed as Recent include, in the first place, the gravels and sands of the present streams, together with their flood-plains and the lower terraces, and, secondly, the material forming the present sea-beach and the lower portions of the coastal plain. Thus the Recent auriferous deposits may conveniently be considered under the headings of—

(*a.*) Fluviatile gravels and sands (including residual or semi-residual deposits).

(*b.*) Marine gravels and sands.

(a.) Fluviatile Gravels and Sands.

The banks and beds of most of the streams of the subdivision contain at least traces of gold, and in many cases have been tested with profitable results. Both banks of the Buller, in particular, have been worked at a number of places, the chief of which are Tiroroa (Twelve-mile) and the historic "Old Diggings" near Berlin's. Other localities are below the Blackwater junction and between Three-channel Flat and Pensini Creek. The workings were chiefly on small flats 30 ft. or 40 ft. above the ordinary level of the river. When the river was low many of the gravel beaches from Hawk's Crag upwards yielded at least wages to men working with cradles, small sluice-boxes, or similar appliances. Since 1890 all these beaches, except those below the Blackwater, and the ordinary water-channels where gravel-bearing, have been dredged (see Chapter II, pages 26–28). There remain only one or two beaches near Hawk's Crag known to contain gold, and these in themselves do not warrant the expense of a dredge. The beaches lower down the Buller are probably valueless.

* See "Handbook of Gold-milling," by Henry Louis, 1894, pp. 16–19, &c.

A small amount of alluvial gold, doubtless derived from the auriferous lodes in its watershed, has been obtained from the gravels of New Creek.

The Mackley River, according to report, is gold-bearing, and has been tested by a considerable number of parties, but these have met with little success. The only old workings of any consequence are situated on the banks of Stevenson Creek, a branch that rises near Cedar Creek Saddle and drains an area of Aorere rocks.

The only other tributaries of the Buller within the subdivision that have yielded any gold worth mention are the Blackwater River and Cascade Creek. The former stream, however, contains very little gold, and the only workings now visible consist of a small sluiced patch of gravel on the east bank about a mile above its junction with the Buller. The bed and banks of Cascade Creek have been worked at intervals from a point three or four miles above its mouth to the neighbourhood of V 37 Creek. Some coarse gold is said to have been obtained from Cascade Creek gravels. Here also the head of V 8 Creek, south of Coalbrookdale, may be mentioned as gold-bearing.

Practically nothing is on record concerning the alluvial gold obtained in the beds of Ballarat Creek, German Gully, Deadman's Creek, Christmas Creek, and other small streams draining the slopes of Mount Rochfort and the adjoining high-level terraces. Their gold, however, may be regarded as derived from the auriferous Pleistocene gravels, both marine and fluviatile, and hardly needs separate consideration.

The Whareatea near its head, in a locality not more than a mile south of Coalbrookdale, has been worked quite extensively, especially at a spot where there is a small flat covered by a few feet of gravel, composed chiefly of greywacke. Its tributary, Trent Creek, has also been worked to a small extent. It is difficult to say whence the gold and accompanying gravel have come, both as regards the Whareatea and V 8 Creek, for no gold-bearing rocks outcrop in their watersheds. The immediate source may have been the coal-measure conglomerates that once covered the area to the southward drained by V 37 and Vincent creeks, where greywacke, granite, quartz-porphyry, &c., now outcrop.

The lower part of the Waimangaroa River gorge has been worked for gold since the early days of alluvial mining in the Westport district until recent years. Occasional rich, if inextensive, patches, together with a number of small nuggets, have been found. The gold is obviously derived from lodes in the Aorere greywackes and argillites, which outcrop extensively in the gorge.

Near Kiwi Compressor, Upper Waimangaroa, are some curious minor occurrences of alluvial gold. One of these is in a little gully where Aorere argillite outcrops over a small area. Another is an ancient pothole in grits, close to the compressor, and 50 ft. or 60 ft. above the Waimangaroa, which on being cleaned out was found to contain some gold. Small quantities of alluvial gold have been obtained at various other spots on the Denniston uplands (the so-called "plateau"). The source of the gold is not always easy to trace. The auriferous material, probably worked about 1890, on Cedar Creek Saddle, north of Mount William, consists of shingly fragments of greywacke and argillite, which are but little water-worn, and are accompanied by very little quartz. It would seem that this deposit, situated at a high level, almost on the top of a ridge, is essentially residual in nature, its gold being probably derived from a neighbouring auriferous zone in the Aorere rocks. From this source also came the gold won from the bed of Cedar Creek itself.

Dufty, Patten, Chatterbox, and other small creeks between Ngakawau and Mokihinui have yielded a good deal of gold, clearly derived, as previously mentioned, from marine Pleistocene gravels and sands (old beach leads). A little gold may occur towards the head of Watson Brook, a tributary of Charming Creek.*

Hodges Creek, a tributary of Rough-and-Tumble Creek, which drains the eastern flank of Mount Kilmarnock, has been extensively worked for alluvial gold, evidently derived from the Aorere rocks that outcrop in its watershed.

(b.) Marine Gravels and Sands.

The marine deposits of Pleistocene age insensibly pass into those considered as Recent, and hence no hard-and-fast line of division can be drawn. There is probably a great deal of gold buried in the modern part of the coastal plain, but only comparatively small portions have been worked for gold.

The marine gravels and sands immediately behind the beach at Constant Bay were worked with good results in the earliest days of the Charleston district. At Rahui, a mile to the north, where old beach deposits have been extensively worked, Powell's claim has been more or less continuously operated on a large scale for many years. Several leads not far from high-water mark are being sluiced, the material being hydraulically elevated and then passed over gold-saving tables. These in 1898 consisted of eight amalgamated copper-plate tables, each 6 ft. by 6 ft., followed by as many baize-covered tables of the same size.† In later years the copper plates may have been discarded. The black-sand here is fine and scaly.

Near the mouth of the Mokihinui a buried beach lead was discovered in 1865, and after being worked for some years was abandoned as exhausted. In 1887 or thereabouts a continuation of the lead was found, but apparently this was of no great extent, and was soon worked out.

South of Ngakawau and near Birchfield the marine deposits have been tested by dredging and in other ways, but at the present time no work is being done. Within the last few years auriferous beach deposits between Fairdown and the sea have been prospected with favourable results. The lead now being worked by the Carthage Gold-mining Company lies beneath 20 ft. or more of sand, at about sea-level. The material is hydraulically elevated to a wide spread of tables, covered with plush mats, on which the gold collects with somewhat coarse black-sand. The concentrate from the mats is treated in an amalgamating-barrel in order to recover the gold-content. The published weekly returns vary from 20 oz. to 50 oz. or more.

A very large amount of gold has been won from the present sea-beaches by "black-sanding." The concentration of the gold with the ironsand is effected by wave-action, and consequently, after favourable weather, some gold can always be obtained from the beach-sands by the treatment of the latest concentrate.

The black-sands have been worked along almost the whole foreshore from near Charleston to north of the Mokihinui. In this length of coast, however, many portions are poor, whilst others—as, for example, at Rahui ("The Beach")—are, or rather were, particularly rich. Most of the gold in the beach-sands subject to sea-action has now been removed by repeated working. Immediately north-east of Westport, however, the sea has been cutting into the land during the past few years, and thus a fresh supply of gold has been added to the beach deposits in this neighbourhood.

UNWORKED AURIFEROUS GRAVELS AND SANDS.

The marine gravels and sands of the coastal plain from Four-mile Creek and Charleston to Mokihinui vary in depth from a few feet to 60 ft. or more, and are

* Fifth Ann. Rep. of N.Z. Geol. Surv., 1911, p. 6.
† Mines Report, C.-3, 1899, p. 108.

everywhere more or less auriferous. Although the known richer patches are practically worked out, there are undoubtedly black-sand leads still to be discovered which would be profitable to work, but whether a systematic search for these would be advisable is another question. One exception to this statement may be made. Several of the known leads are at the base of terraces, and this is not an accident, but due to the concentration of gold derived from the terrace during the wave-cutting period. Hence all terrace-bases ought to be carefully prospected wherever this has not already been done by the early miners and their successors. Reference may here be made to the raised auriferous beaches at Nome, several of which occur at the foot of small terraces.* A consideration of the known geological factors will help in such a search, but of greater value would be a full record of the claims worked out by the old miners and of the prospecting done by them. It is believed that much of the poorer material in various localities contains enough gold to render its working profitable, if only an adequate supply of water could be obtained at a moderate expense. Many years ago it was proposed to bring a water-race from the Ohikanui River to Addison's, but this very expensive scheme fell through, and it is obviously now impossible to recommend it. Other obstacles in working the low-grade gravels are the lack of fall for tailings and the great length of the necessary drainage-tunnels.

CHARACTER AND QUALITY OF ALLUVIAL GOLD.

The gold associated with the black-sand leads of Charleston, Addison's Flat, Bradshaw's, Fairdown, and Mokihinui is in very small particles, and much of it, indeed, floats so readily on water that it is easily lost, whilst, as stated on an earlier page, a great proportion is either non-amalgamable or amalgamates with great difficulty, owing to the presence of a supposed coating of iron-hydroxide. The gold obtained in the stream-beds, except where derived from marine deposits, is generally fairly coarse, and is thus, as the diggers term it, "a good sample." The small nuggets of the Waimangaroa have already been mentioned, and it may be of interest to record that in Little Flaxbush Creek, near Three-channel Flat, a 40 oz. nugget was found, whilst in some workings on the west side of the Buller near Rocks Bar or Rocky Fall (between Three-channel Flat and Lyell) a nugget weighing 95 oz. 5 gr. was obtained.†

Exact information concerning the quality of the alluvial gold of the Buller-Mokihinui Subdivision as ascertained by analysis is not available. The gold from the marine deposits (black-sand leads, &c.) is, when freed from the adherent iron-oxide, &c., almost pure. For many years the bank price of Charleston gold was stated in the Mines Reports to be £3 19s. per ounce. To obtain the Mint value of this gold allowance must be made for the bank's profit and for accidental impurities, such as adhering oxide of iron. The gold near Westport is worth from £3 17s. to £3 18s. per ounce, and that of the Lyell district £3 17s. and upwards. The usual price obtained by the Buller dredges for their gold seems to have been about £3 18s. per ounce.

SOURCE OF ALLUVIAL GOLD.

The ultimate main source of the alluvial gold of the subdivision is, without doubt, auriferous veins and zones in the greywackes and argillites of the Aorere Series. The granites and gneisses of the area under consideration are nowhere known

* T. A. Rickard: "Geology applied to Mining." *Mining Magazine*, vol. xi, October, 1914, pp. 251–59.
† Information from Mr. V. Dellavedova. The localities are outside the area described in this report.

to be auriferous, and thus resemble the granitic rocks of other parts of the South Island, which are everywhere practically non-auriferous, the only known but unimportant exception being the granite of Mount Rangitoto, North Westland, which in places contain traces of gold.* It ought to be added, however, that small amounts of alluvial gold have been reported as occurring on other granitic mountains in Westland, and while this report is passing through the press one of the writers has been shown a specimen of granite from the Oparara district, near Karamea, that contains visible gold.

The alluvial gold of Hodges Creek, the Waimangaroa River, Cascade Creek, Stevenson Creek, and New Creek is, as mentioned on previous pages, directly derived from Aorere rocks in the immediate neighbourhood. In places a little gold in the Quaternary deposits may have been derived from the coal-measure conglomerates, &c. The gold of the Buller River has been transported some distance, and its sources cannot well be determined. Some has come from the Aorere rocks of the Lyell district, and some from similar rocks that once occurred on the slopes of the Brunner Range to a much greater extent than they do now.

The small amounts of gold in the coal-measure conglomerates and in the Hawk's Crag breccia may by inference be considered as derived mainly from quartz veins in Aorere rocks.

There is some difficulty in ascertaining the source of the enormous amount of fine detrital gold in the marine Quaternary deposits of the subdivision. The gold is evidently far-carried, and cannot have been derived from the Aorere rocks as now developed in the subdivision, which, though almost everywhere gold-bearing, are known to be strongly auriferous only at Stony Creek. Perhaps some gold has been derived from Aorere rocks that once covered portions of the Paparoa Range, whilst some may have been carried up the coast by the waves and currents of the sea. It is probable, however, that a great part of the gold in the marine deposits has been brought down by the Buller River. Hector in 1868 writes, "I believe that this fine gold must have been deposited by the Buller and other rivers, and that it is not due to the extension up the coast of the surf-carried gold derived from the 'leads' along the main range in the south."†

Hector regarded the transported gold as having been derived from the terrace country intersected by the Buller and its tributaries, but does not state the ultimate source of the gold in the terraces.

McKay has fully discussed the origin of the Westland alluvial gold.‡ He considers this as derived mainly from the Moutere gravels of Pliocene age, and these again have obtained much of their gold from the coal-measure conglomerates and breccias. The ultimate source of the gold he believes to be argillites and greywackes (slates) of Carboniferous or Maitai age. These are the Greenland rocks of Bulletins Nos. 6 and 13, and the Aorere rocks of the present bulletin. McKay further believes that the Palæozoic rocks which were the real source of the alluvial gold of to-day formed a mountainous land to the west of the present sea-coast. He writes, "Much of the gold of the west coast could not have been, and was not, supplied to the low grounds from an easterly direction."§ The reader may

* J. R. Don: "The Genesis of certain Auriferous Lodes." Trans. Amer. Inst. Min. Eng., vol. xxvii, 1897, p. 652.

† "Abstract Report of the Progress of the Geological Survey of New Zealand during 1866–67." G.S. Rep. No. 4, 1868, p. 32. In the version of this report published in 1867, only the Buller River is mentioned (p. 14.)

‡ "Geological Explorations of the Northern Part of Westland." Mines Report, C.-3, 1893, pp. 173–82. See also Rep. G.S. during 1892–93, No. 22, 1894, pp. 11–50.

§ *Loc. cit.*, p. 182. Rep. G.S. No. 22, p. 43.

also be referred to the remarks dealing with the origin of the Westland alluvial gold in Bulletins Nos. 6 and 13.*

The writers of this bulletin are unable to present any fresh evidence bearing on the origin of the alluvial gold of the Westport district.† Unfortunately the alluvial mining industry is at present in so decadent a condition that it neither furnishes data on which to found speculations, nor is it important enough to call for prolonged and expensive investigation. McKay had the opportunity of seeing the alluvial mines soon after the period of maximum production, and his conclusions may be accepted as substantially correct in most respects. Some exception may perhaps be taken to his hypothetical western range as unnecessary. The writers, however, have made no observations that are inconsistent with its existence. On the contrary, some evidence in its favour has been obtained (see page 79, and Bulletin No. 13, page 51).

MINOR ALLUVIAL DEPOSITS.

Platinum and Osmiridium.

In 1903 Sydney Fry found 8·5 per cent. of platinum in gold bullion from the tail-race of the Rochfort Hydraulic Sluicing Claim.‡ According to Kenneth Ross,§ platinum was also obtained by Mr. Fry in concentrated material from Whareatea Creek, Christmas Terrace (Fairdown), and Bradshaw's. It has also been reported by the Dominion Laboratory‖ in sand from German Terrace Analyses of samples of platinum-bearing concentrates from Fairdown, and from the Shamrock Claim, Addison's are given on previous pages (115, 117).

Osmiridium has been reported from the Mokihinui beach lead,¶ and also from the Whareatea River.**

It is probable that in past years many ounces of platinum were discarded from the auriferous gravels of the Fairdown and perhaps other districts. At the present time the known occurrences are of little economic importance, though obviously the gold-miners of the Westport district ought to save their concentrates and have them regularly analysed.

The association of chromite with the platinum indicates a common derivation from the serpentine-dunite belt of the western slope of the Southern Alps, or not impossibly from a similar zone in the westerly land postulated by McKay.

Stream-tin.

The presence of stream-tin in the Westport district has been known for many years, and it has been reported from a number of localities. Small quantities are stated by McKay and Sydney Fry (*fide* Kenneth Ross) to be present in the Waimangaroa River gravels. Steam-tin has been found in the Mackley Valley, but the exact locality is doubtful. According to the most reliable account, it occurs in Wilderness Creek, probably a tributary of Stevenson Creek, which has its source near Cedar Creek Saddle. Though panning tests of stream-gravels made by the Geological Survey at several places in the Mackley watershed gave negative results, the occurrence of tin in moderate quantity is not unlikely, for granitic and gneissic rocks cover a considerable area in this quarter.

* N.Z.G.S. Bull. No. 6, 1908, pp. 114–15, 155–56 ; and Bull. No. 13, 1912, pp. 89–90, &c.
† Unless the presence of chromite, platinum, monazite, &c., in the marine deposits can be considered as such (see later paragraphs).
‡ Mines Report, C.–3, 1904, p. 27.
§ *Mines Record*, vol. x, 1906–7, p. 12.
‖ Forty-second Ann. Rep., 1909, p. 31.
¶ Mines Report, C.–5, 1888, p. 36.
** *Mines Record*, vol. iv, 1900–1, p. 161.

Dr. W. H. Gaze in 1888 reported stream-tin from Cedar Creek and Mokihinui.* The gravels of Cedar Creek were tested by panning and in one case by assay of the dish concentrates, but no tin was found. Dr. Gaze's statement, however, probably refers to the gold-workings on the east side of Cedar Creek Saddle† (? Wilderness Creek). The Mokihinui locality is not definitely ascertainable, but is possibly near Seatonville.†

Monazite.

Monazite occurs in trifling quantity, associated with the black-sands of the coastal belt. It has been definitely identified at Bradshaw's, Bull's, and Fairdown by Sydney Fry and by the Dominion Laboratory. Analyses of concentrates from Addison's, Bradshaw's, and Fairdown are given on pages 115–17. Concentrate from Jameson and party's cement claim, Bradshaw's, contained, according to Fry—Thoria, 0·2 per cent.; ceria, oxides of lanthanum, &c., 0·42 per cent.‡

Ironsand.

Since the black- or iron-sands of the subdivision have been regarded as a possible source of iron, some remarks on the subject may here be made. The auriferous cements of Charleston and neighbourhood certainly contain a large amount of iron, but under present conditions cannot be regarded as iron-ores. The deposits are too impure to be smelted without concentration, which would present various difficulties, such as the loss of hydrated brown oxide of iron on the one hand, and the retention of zircon and various other heavy minerals on the other. Again, smelting the concentrated sand is hardly a commercial proposition at the present time, for it is highly titaniferous, as shown by the analyses on pages 115–17. Auriferous ironsands from the Lower Buller, according to Hector, analyse as follows: Magnetite, 54·0 per cent.; "titanite" (? ilmenite), 42·3 per cent.§ Skey, however, records two samples of a "wash from the Westport district, formed of mixtures of hæmatite and magnetite, and containing 66·4 and 67·6 per cent. of iron respectively.‖ Further information concerning the ironsands of the district may be obtained from McKay's paper entitled "Notes on the Auriferous Ironsands of New Zealand."¶

BARITE.

Many years ago barite was reported to occur in some quantity at Cascade Creek,** and Dr. Gaze writes that it is there associated with flourspar.†† These statements, however, require some confirmation before they can be accepted. In 1902 a nearly pure sample of barite sent from Westport was analysed at the Waihi School of Mines.‡‡ The source of this specimen, according to the sender, Mr. P. Hennessey, was near Millerton, and during the past few years the presence of the mineral in this locality, and also at Coalbrookdale, has become generally known.

The Coalbrookdale occurrence consists of small lenticular irregular veins in quartz-porphyry near the tunnel through which the Westport Coal Company's rope-line passes. None of these is more than 2 in. or 3 in. thick, or more than a few feet in length.

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* "An Introduction to Analytical Pyrology," 1888, p. 46.
† See also Handbook of New Zealand Mines, 1887, p. 221.
‡ Mines Report, C.-3, 1905, p. 27.
§ "Handbook of New Zealand," 1886, p. 46.
‖ Lab. Rep. No. 18, 1883, p. 47.
¶ *Mines Record*, vol. i, 1897–98, pp. 395–96, and 446–50. Reprinted separately in 1901.
** Mines Report (Warden's Reports), 1887, p. 136.
†† *Op. cit.*, p. 65.
‡‡ Mines Report, C.-3, 1903, p. 68.

During the course of the recent geological survey a number of small barite veins were located in coal-measure grits on or near the Westport-Stockton Coal Company's lease two or three miles south-east of Millerton. Three of these are close to trig. station AH, whilst three others are nearly a mile away, on the south side of the Mangatini fault. The veins are from a fraction of an inch to 6 in. or 7 in. in width, and none can be traced for more than 30 ft. The strike of most is north-west and south-east, and the dip almost vertical.

The barite veins are too small and too remote from a market to be of commercial value, for the value of the crude mineral at the shipping-point is probably not more than 12s. 6d. to 15s. per ton.

The veins have without much doubt been formed by downward descending solutions during the period when erosion of the once-overlying rocks was proceeding. The barium was perhaps extracted from the Kaiata mudstone. It is of interest to note that various barite-deposits in other parts of the world have been formed by downward decension combined with lateral secretion—for example, the veins near the village of Five Fingers, Nova Scotia.*

The following analyses of the Westport barite have been made:—

	(1.)	(2.)	(3.)	(4.)
Barium sulphate	98·33	90·60	98·72	92·10
Silica	n.d.	2·75	0·31	..
Ferric oxide (Fe_2O_3) and alumina (Al_2O_3)	1·69	3·87	0·04	..
Lime	Traces	Nil	0·14	..
Strontia	Doubtful trace	Nil	0·06	..
Magnesia	Trace	0·70	n.d.	..
Moisture lost at 100° C. ..	0·04	..	..	..
Loss on ignition	0·19	1·16	..	..
Water and organic matter ..	..	..	0·73	..
Undetermined (including alkalies)	..	0·92	..	..
	100·25	100·00	100·00	

(1.) Sample analysed at Waihi School of Mines by P. G. Morgan in 1902. (Mines Report, C.–3, 1903, p. 68.)

(2.) Barite from Coalbrookdale.

(3.) Barite from 6 in.–7 in. vein near bore on T 35 Creek, one mile south of trig. station AH.

(4.) Probably from vein some distance west of bore on T 35 Creek.

Mica.

Pegmatitic veins containing plates of mica 1 in. or more in diameter are not uncommon in the gneissic rocks of the subdivision. Near Charleston, and about 20 chains south of west from Constant Bay, is a vein or mass of coarse pegmatite, which during part of 1911 and 1912 was worked for its mica-contents. About 2 tons of the mineral, much of which, it is understood, was not in the form of merchantable sheets, but merely scrap, was exported to England.† Though plates measuring as much as 6 in. by 4 in. can be obtained, the proportion of sheet mica

* *Mining and Scientific Press*, 22nd January, 1910, vol. c., p. 158.

† Mines Report, C.–3, 1912, p. 63.

to barren rock is too small to enable the pegmatite to be profitably worked unless richer patches can be found. Some of the mica is cross-grained, and all seen by the writers is somewhat dark in colour, whilst that near the surface has been affected by weathering, but any defect of this kind would, of course, disappear in depth. So far as known, no test of the insulating-strength of the mica has been made.

The occurrence of mica in large plates at Charleston was known many years ago, for Liversidge in 1878 mentions muscovite-mica from that locality. He describes it as brown in colour, with greenish shades and metallic lustre, and gives the following analysis :—*

Silica	45·007
Iron-sesquioxide	4·138
Alumina	37·144
Potash	10·049
Lime	0·517
Magnesia	1·286
Undetermined constituents, water, soda, &c.	1·859
	100·000

The following complete analyses of Charleston mica, made in the Dominion Laboratory during 1914, are (1) of brownish merchantable sheets, and (2) of cross-grained material :—

	(1.)	(2.)
Silica (SiO_2)	44·19	44·83
Alumina (Al_2O_3)	32·15	33·27
Ferric oxide (Fe_2O_3)	4·20	4·00
Ferrous oxide (FeO)	1·15	1·15
Manganous oxide (MnO)	0·10	0·05
Titanium-dioxide (TiO_2)	0·35	0·50
Lime (CaO)	Nil	Nil
Magnesia (MgO)	0·86	0·54
Potash (K_2O)	10·31	10·44
Soda (Na_2O)	0·17	0·06
Lithia (Li_2O)	Trace	Trace
Phosphoric anhydride (P_2O_5)	0·09	0·10
Sulphur-trioxide (SO_3)	0·10	0·06
Carbonic anhydride (CO_2)	Nil	Nil
Water below 100° C.	1·43	0·66
Combined water	4·49	4·50
	99·59	100·16

Miscellaneous Economic Minerals.

The list of minerals printed as Appendix I to this report contains references to the following minerals and metallic ores, as well as to others of possible economic importance: Graphite, galena, spathic iron-ore, manganese-ore, alum-shale, copper-ore, cinnabar, potash-feldspar, bismuth, monazite,† topaz, zircon, &c.

* "Notes on some of the New Zealand Minerals belonging to the Otago Museum." Trans., vol. x, 1878, pp. 497–98.

† See also p. 123.

It may be as well to mention here that orthoclase (potash-feldspar) forms a large proportion of the Charleston pegmatite dyke mentioned under the heading of "Mica," and described on page 102. When a practicable process for the recovery of potash from potash-feldspar and other potassium silicates, such as muscovite-mica, has been discovered it is probable that the Charleston pegmatite and perhaps other similar occurrences will be utilized in the manufacture of potassium salts.

Building-stones, etc.

The Miocene limestones of the Charleston, Cape Foulwind, and Mokihinui districts could be used locally for building purposes. The limestone near the Little Totara Stream is flaggy, and probably more suitable for use as a building-stone than that of the other localities named.

The grits and sandstones of the bituminous coal-measures have been used in the construction of stone walls and dams near Denniston, Millerton, and elsewhere. In places these rocks could be quarried for building purposes if local demand existed.

The greywacke and hornfels of the Aorere Series are generally tough, hard rocks, but, owing to the joint-planes, where these exist, tending to intersect at angles well removed from a right angle, could not be quarried, as a rule, without much waste.

Though not as a rule of ornamental quality, the granites and gneisses of the subdivision can furnish an inexhausible supply of building-material. They are, however, seldom well jointed. The gneissic granite of Cape Foulwind is, as mentioned in Chapter II, extensively quarried in order to supply material for the moles at the mouth of the Buller River.

Ganister.

Ganister is largely used for lining steel furnaces (in the acid-hearth process) and for the manufacture of firebrick. It is usually defined as a fine-grained siliceous sandstone or grit, the composition of which should be within the following limits: Silica 87 to 96, alumina 4 to 5, ferric oxide 0 to 1·5, lime and magnesia 0·25 to 0·75, alkalies 0 to 1 per cent.* The best Yorkshire ganisters contain 95 per cent. of silica.

On the Denniston and Millerton uplands thick and accessible beds of sandstone occur which undoubtedly comply with the definition of ganister as given above. Of no present economic importance, these sandstones in the future may prove very useful in the manufacture of siliceous firebricks. Experimental work and practical tests will, of course, be necessary to determine the real value of the Westport sandstones as refractory materials. Much of the British ganister, as Searle observes, is useless except for road-metal, because it contains too high a percentage of impurities. The attention of the writers was directed to the possible ganister qualities of the bituminous coal-measure sandstones by Mr. J. Bradley, chemist to the Westport Coal Company.

Road-making Material.

The Buller-Mokihinui Subdivision, unlike some parts of New Zealand, does not suffer from the want of cheap and easily obtained road-making material. For this purpose the gravels of the coastal plain, river-flats, and stream-beds are generally used. The stream-gravels commonly contain many overlarge pebbles, but when these are removed or broken to a smaller size make tolerably good roads. The marine gravels, both ancient and modern, though usually free from large stones, do not bind

* Alfred B. Searle: "An Introduction to British Clays, Shales, and Sands," 1912, p. 181.

well, owing to the absence of clayey material; they therefore form roads with many loose pebbles on their surfaces. On the Denniston and Millerton uplands bituminous coal-measure sandstone and grit are a good deal used for road-making purposes, and though not ideal materials, owing to their somewhat rapid disintegration into sand with poor binding-qualities, answer sufficiently well where used judiciously. Near Burnett's Face the outcropping Aorere rocks and quartz-porphyry are being quarried for road-making purposes. The granites and limestones of the subdivision are also being used to a limited extent as macadamizing materials.

Limestones suitable for the Manufacture of Lime and Cement.

Eocene Limestones.

Towards the head of Fletcher Brook, a branch of Charming Creek, limestone appears in a low horizon of the Kaiata beds. As shown by analysis, it is here of good quality, and well adapted for the manufacture of lime or cement, but the area over which suitable rock outcrops is small, and the locality is many miles from Westport, which is practically the nearest shipping-point. The substantially constructed tram-line of the Yellow Silver-pine Exploration Company passes in the immediate vicinity, and furnishes transport facilities to the rail-head at Mokihinui Mine, less than three miles away, so that possibly lime could be advantageously made in a small way for local use.

South of Fletcher Brook calcareous rocks outcrop in St. Andrew and St. David streams, but are in general too impure to be of any value, though in St. Andrew Stream the material at one place may have the composition of an hydraulic limestone. Analysis No. 2 below is not from the outcrop to which reference is made, but represents more siliceous material.

Miocene Limestones.

Though limestone is abundant in the Oamaru rocks, is is not everywhere sufficiently pure to have much value for commercial purposes. Thus north of the Mokihinui the calcareous rocks as a rule are arenaceous, argillaceous, or both, though in places fairly suitable for the manufacture of lime. At the north end of the bridge over the Buller south of Lyell a thick and fairly good limestone forms a cliff in which roadways have been cut for several chains. Flaggy but impure limestone outcrops in Pensini Creek two miles from its mouth. Limestone is seen in the eastern part of Ohika Survey District, and some in the watershed of Nada Creek is of moderately good quality.

The best limestone in the subdivision, and also that most favourably situated for the manufacture of lime and cement, is in the neighbourhood of Cape Foulwind, where it was for some years quarried by the Westport Harbour Board, and at the present time is being used to a small extent for making lime. The rock outcrops over an area of about 80 acres, and at least 6,000,000 tons are available for cement-manufacture. The interested reader may be referred to a special report* for fuller particulars of the cement possibilities.

Seven or eight miles south of Cape Foulwind limestone outcrops near the mouth of the Totara River. Thick flaggy limestone appears on the roadside south of the Little Totara River, whilst from the Waitakere River to the southern boundary similar rock forms prominent escarpments at a distance of two miles to one mile from the coast. In general the limestone of the Charleston district is apparently of good quality, and for agricultural purposes there is an inexhaustible supply. At some future time the manufacture of cement may become feasible, but the distance from a shipping-port will always be a drawback.

* P. G. Morgan: "Cement Materials near Cape Foulwind." Seventh Ann. Rep., N.Z.G.S., 1913, pp. 126–28.

Analyses.

The following analyses, all except the last, of samples collected by the writers, may be quoted :—

——	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Silica (SiO_2)	3·41	30·00	32·82	5·65	7·34	36·10	2·03	2·20	16·58	0·85	2·15
Alumina (Al_2O_3) ..	0·30	3·78	2·94	0·38	1·20	0·70	1·12	1·10	2·97	0·50	0·51
Ferric oxide (Fe_2O_3) ..	1·06	1·58	1·74						2·08		0·57
Lime (CaO)	52·32	32·03	32·45	52·08	49·78	34·80	53·48	53·08	41·65	55·25	52·95
Magnesia (MgO) ..	0·96	1·67	0·89	0·56	1·05	0·50	0·82	1·43	1·40	0·30	0·53
Carbonic anhydride (CO_2)	40·98	25·70	24·34	40·20	39·60	27·50	42·14	41·80	32·90	42·60	42·40
Phosphoric anhydride (P_2O_5)	0·05	0·06	0·08	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	..
Titanium-oxide (TiO_2) ..	0·02	0·10	0·11	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	..
Water and organic matter	0·56	3·85	4·20	0·60	0·17	0·20	0·30	0·18	0·90	0·15	0·40
Alkalies and undetermined	0·34	1·23	0·43	0·53	0·86	0·20	0·11	0·21	1·52	0·35	0·49
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00

(1.) Limestone, Fletcher Brook.
(2.) Impure limestone, St. Andrew Stream.
(3.) Arenaceous limestone, New Inland Karamea Road.
(4.) Limestone, near Lyell Bridge, Buller River.
(5.) Limestone, Cape Foulwind Beach.
(6.) Calcareous grit, Cape Foulwind Beach.
(7.) Limestone from quarry, Cape Foulwind.
(8.) Drillings from upper part of bore in limestone quarry, Cape Foulwind.
(9.) Drillings from lower part of bore in limestone quarry, Cape Foulwind.
(10.) Limestone south of quarry, Cape Foulwind.
(11.) Limestone from Cape Foulwind, forwarded to Dominion Laboratory in 1911 by H. R. Young.

The following references to analyses made by W. Skey and recorded in the Dominion Laboratory reports may be useful :—

Lab. Rep. No. 23, 1889, p. 54 : Two limestones from Cape Foulwind contain 96·75 and 92·61 per cent. carbonate of lime.

Lab. Rep. No. 25, 1891, p. 57 : Two concretionary limestones from the vicinity of Cape Foulwind contain 91·30 and 90·62 per cent. carbonate of lime. Magnesia and other constituents are determined.

Lab. Rep. No. 27, 1893, p. 28 : A limestone from Cape Foulwind contains 93·18 per cent. carbonate of lime, and 3·12 per cent. carbonate of magnesia. Other constituents are iron-oxides 1·26 per cent., siliceous matter 2·03 per cent., and water 0·41 per cent.

Lab. Rep. No. 33, 1900, p. 10 : A very pure limestone from Cape Foulwind contains 95·22 per cent. carbonate of lime, 2·46 per cent. carbonate of magnesia, 0·84 per cent. iron-oxide, 0·63 per cent. alumina, 0·64 per cent. siliceous matter, and 0·24 per cent. water.

Clays and Claystones.

The mudstone of the Kaiata beds is probably fairly well adapted for the manufacture of ordinary bricks, tiles, drainpipes, &c., and with the addition of siliceous material may in places be capable of making moderately refractory firebricks. Much of it is suitable for admixture with lime in the manufacture of Portland cement.

The Miocene claystones, where not too sandy or calcareous, can be used for brickmaking, and in places material apparently suitable for tiles and for some classes of potteryware exists. From Cape Foulwind claystone excellent terra-cotta ware has been experimentally produced. The more calcareous or " marly " claystones where favourably situated will find a use as cement materials, and elsewhere may be found useful for local application as a soil-fertilizer. With the exception of the clay from Seddonville mentioned in the next section, Recent clays, save as minor deposits formed by the weathering in place of Tertiary mudstone, claystone, or limestone, are practically non-existent in the subdivision.

Fireclays.

Very little fireclay is associated with the coal-seams of the Westport district. In places the dark shales interbedded with the grits, sandstones, and coal-seams with or without admixture with other materials may be found suitable for the manufacture of firebricks, &c. A light-coloured very soft and plastic clay from the vicinity of the haulage road to the old Cardiff Mine, Seddonville, about half a mile from the State Coal-mine bins, has been used in a small way as a fireclay with some success. Its composition is shown by analysis No. 6 below. Similar material is said to occur near Mokihinui Mine.

Analyses.

	(1.)	(2.)	(3.)	(4.)	(5.)	(6.)
Silica (SiO_2)	50·12	52·05	61·30	62·30	47·55	60·13
Alumina (Al_2O_3) ..	16·75	18·26	15·43	16·68	19·36	23·42
Ferric oxide (Fe_2O_3) ..	7·45	5·09	8·08	7·12	7·80	2·52
Titanium-dioxide (TiO_2) ..	n.d.	n.d.	n.d.	n.d.	0·98	n.d.
Lime (CaO)	5·86*	4·80	1·90	2·20	4·18	0·10
Magnesia (MgO)	0·38	1·73	2·01	1·47	1·84	0·53
Soda (Na_2O)	3·48	3·47	6·18	5·70	0·98	2·55
Potash (K_2O)					2·16	
Carbonic anhydride (CO_2) ..	4·61*	1·40	n.d.	n.d.	4·00	n.d.
Water at 100° C.	11·35	12·75	5·10	4·53	3·77	2·25
Combined water and organic matter					7·53	8·80
Undetermined	..	0·45	..	..	..	..
Total	100·00	100·00	100·00	100·00	100·15	100·30

* Recalculated from calcium-carbonate, 10·47 per cent.

(1.) From Cape Foulwind. See Dom. Lab. Rep. No. 39, 1906, pp. 7–8.
(2.) From Cape Foulwind. See Dom. Lab. Rep. No. 45, 1912, p. 15.
(3.) From Cape Foulwind cliffs, in horizon well above limestone.
(4.) From Cape Foulwind cliffs, in horizon just above limestone.
(5.) Calcareous mudstone, Buller Gorge Road, east of Coal Creek, Inangahua Survey District (not in subdivision).
(6.) Fireclay, near haulage-road to old Cardiff Mine.

The Miocene claystones below the limestone horizon are more argillaceous and also more calcareous than those above, which tend to pass into impure fine-grained sandstones. This is shown by analyses (1) and (2) believed to represent samples from the lower horizon, and also by analysis (5).

Testing Clays, &c.

The value of a clay for most purposes other than cement-manufacture cannot be determined by chemical analysis, even when this is taken in conjunction with its physical characteristics, so that laboratory tests for tensile strength, fire and air shrinkage, absorption, fusibility, &c., generally afford much more reliable information. In many cases special tests, varying according to the purpose for which the clay is to be used, are necessary before an opinion as to its value can be given. Without doubt the clay rocks of the Westport district, in common with those of other parts of New Zealand, have great potential value, but before they can be practically utilized a population sufficiently large to create an adequate demand, and expert knowledge fully capable of conducting the manufacture of clay goods in a proper manner, are required.

COAL.

As already stated in Chapter V, the coal of the Buller - Mokihinui Subdivision belongs to two distinct formations, one of probable Eocene and the other of Miocene age. The Eocene coal in the main is bituminous (humic), whilst the Miocene coal, except where it has been strongly affected by earth-movements, as in Blue Duck Creek (a tributary of the Mackley) and near Three-channel Flat (Inangahua Survey District) is brown coal containing 10 to 20 per cent. of water. Hence the description of the coal resources of the Westport district naturally falls under two heads (I) bituminous or humic coal, and (II) brown coal.

(I.) BITUMINOUS OR HUMIC COAL.

General Description.

The principal area containing bituminous or Eocene coal extends northward from Mount Rochfort to the Mokihinui River as a not very wide strip, bounded on the west by the Kongahu or Lower Buller fault, and on the east partly by the Mount William fault and partly by an indefinite line drawn northwards from the point where the latter fault appears to die away. This region has been well explored, and contains all the producing mines of the Westport district. To the eastward is a little-known block of coal-bearing country, the southern part of which is drained by the Mackley or Orikaka River, and the northern part by the Ngakawau and other streams. The Glasgow fault sharply defines its eastern boundary, beyond which no Eocene rocks are found. Together the two areas just delimited form the greater part of the Papahaua end of the Paparoa earth-block, described in Chapter III, and again mentioned in Chapters IV and V. It may be as well here to repeat that this portion of the Paparoa block, though strongly uplifted in the neighbourhood of Mounts Rochfort, William, and Frederick, has on the whole a pitch to the northward, so that the coal-horizon found at heights of considerably over 3,000 ft. on the three mountains is near, or even below sea-level in Charming Creek valley and near Seddonville. The block, moreover, is tilted to the eastward, so that the coal near the Glasgow fault is in places not much above sea-level. The major faults and changes of dip and strike affecting the bituminous coal-measures have been described on earlier pages, whilst many minor variations in structure are shown by the geological maps.

The uplift of the Paparoa-Papahaua earth-block has enabled denudation to expose countless coal-outcrops, and has brought almost the whole of the known coal above the general drainage-level, so that it can be worked without hoisting or pumping shafts. Unfortunately, however, erosion has gone so far that an enormous amount of coal has been lost, and the coal-measures have been entirely stripped from large portions of the field. Particularly on the Mount William Range and in the Mackley Valley have the denuding agencies been overactive. Again, even in those areas where the Eocene rocks still remain, exploration has shown that the workable coal occurs in decidedly lenticular deposits, and that considerable portions of the coal-measures are practically devoid of coal. Thus estimates of the quantity of coal based on outcrops alone are liable to be exaggerated.

Coal-seams.

There are several seams of coal in the Westport district, but only over comparatively small areas are as many as two beds, workable under New Zealand conditions, found one below the other; and even then the one is really a split from the other, and not a distinctly separate deposit. Owing to the lenticular nature of the coal-seams, and their decided variations in physical and chemical properties, exact correlation of the various outcrops becomes practically impossible. The truest statement of the case seems to be that there is but one main seam, which in places dies out, in other places may divide into splits. These splits may locally attain great thickness (50 ft. or even more), but where they do so the other part has usually either altogether thinned out or become unworkably thin. Subject to the limitations just mentioned, the main seams in different localities may be given corresponding place-names, it being understood, however, that they are neither necessarily distinct nor yet without doubt one and the same. Thus in the Seddonville district there is the Seddonville seam; near Mokihinui Mine the Hut seam; at Mangatini and Mine Creek the Mangatini seam (found to be an upward split from the Matipo seam, developed in the eastern part of the Westport-Stockton lease); at Burnett's Face and Coalbrookdale the Coalbrookdale seam (with splits); in the upper Blackburn Valley the Blackburn seam; and so on. In many places from 50 ft. to 100 ft. above the main body of coal an apparently distinct minor seam from 1 ft. to 3 ft. thick is observable (as well as still smaller layers). It will sometimes be convenient to speak of this as the upper seam, though probably in some parts of the district the upper seam of other localities has become the main seam, and is itself overlain by another upper seam. As used in this report, then, the terms "upper" and "lower" seam refer only to the locality being described.

Cox and Denniston speak of an upper and a lower seam, which they supposed remained separate and recognizable throughout the field. Cox, however, on one occasion expresses doubt concerning the correlation of the main seam in the Ngakawau basin (Mangatini seam) with that in the Waimangaroa basin (Coalbrookdale seam).*

Roof and Floor.—As stated in Chapter V, the Eocene coal-seams are associated with shale, sandstone, and grit, the two latter rocks greatly predominating. The immediate roof of the coal is generally a firm sandstone or in places grit. Frequently the first foot or so of the roof is a dark shaly sandstone, which rapidly passes into or is replaced by a coarser-grained rock. In some parts of the field the coal is overlain by shale, which naturally forms a treacherous roof, and lessens the percentage of of coal that can be extracted. The floor usually consists of a few inches of carbonaceous shale, underlain by sandstone and grit. In some places there is hardly any shale, whilst in others there may be many feet. In such cases the roof is likely also to be shale, and ultimately, owing to the thinning of the coal, roof and floor may meet. In several areas a passage of the whole or the greater part of a coal-seam into a dark shale may be clearly observed.

Physical Characters.

The coals from the various seams and localities do not differ markedly in general appearance. Like other bituminous coals they show more or less lustrous surfaces or bands interspersed with duller patches. The coal from the Denniston mines is of

* "Report on Survey of Buller Coalfield." Rep. G.S. during 1874–76, No. 9, 1877, p. 24.

remarkably good appearance, whilst that from Seddonville is on the whole inferior in lustre to the other coals of the district. Some of the brighter coal, notably the Coalbrookdale, has a tendency to fracture conchoidally, but the usual fracture is cuboidal, the coal breaking along the bedding-planes and the nearly vertical joint-planes or "cleat." Incidentally it may be observed that cleat is not well developed in the Westport coal-seams, and therefore has little influence on the method of working.

A striking feature of the bituminous coals is their great variation in ability to resist disintegration, or, as the miner would term it, hardness. At outcrops the coal is generally firm and tough, but exploration reveals the fact that under cover much is extremely friable or "soft."* At the Coalbrookdale end of the field hard coal decidedly predominates, but at the Mokihinui end is much less in evidence.

In places, especially near faults and strong rolls, friable coal has become so much disintegrated by crushing movements that it forms sooty, incoherent material fit only for coking. Such coal is abundant near Waimangaroa, where the coal-measures are involved in the great Kongahu or Lower Buller fault. The very peculiar soft, loose masses known at Seddonville as "doughboys" are described on a later page.

Composition.

The Eocene coals of the Westport district have a somewhat wide range in composition. A sample obtained by W. M. Cooper from a locality not definitely stated had the composition of an anthracite (see analysis No. 15, page 136), and was therefore comparable with the Fox River anthracite. The sooty coal or "culm" from Waimangaroa has a high but variable percentage of fixed carbon. The coal from the Denniston collieries as mined contains from 55 to 60 per cent. fixed carbon, 37 to 41 per cent. volatile hydrocarbons, 1 to 4·5 per cent. water, 0·5 to 4 or 5 per cent. ash, and 0·5 to a little under 3 per cent. of sulphur. The Millerton coal is somewhat higher in fixed carbon and lower in volatile hydrocarbons and water. Sulphur is much higher than in the Denniston coal, ranging from 2 to nearly 5 per cent. The Westport-Stockton coal, though mined from the same seam as the Millerton,† is slightly lower in fixed carbon and higher in volatile hydrocarbons. Mokihinui-Seddonville coal, as compared with the Westport-Stockton, is decidedly lower in fixed carbon, and slightly higher in volatile matter, water, and sulphur.

The differences between the coals from the various localities are to some extent attributable to variations in amount and nature of the present cover, but probably are more closely connected with changes of pressure that took place during the uplift of the coal-measures. How far the differences are due to variation in original composition cannot be stated. Correlation of the several seams or splits on the strength of similarity in composition is very uncertain, for there are considerable variations in one and the same seam as it occurs in different localities. At present no explanation of the increase in sulphur towards the middle and northern parts of the field can be given, but remarks dealing with the sulphur-content of the Westport coals, both bituminous and brown, will be found on several later pages.

It is of interest to note that resin in the form of small lumps is occasionally seen in the Coalbrookdale coal, and, though absent from the Millerton district, is fairly common in the Seddonville-Mokihinui coal. Further observations concerning this substance are made on page 180.

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* The American reader may be reminded that in New Zealand "soft" coal is a synonym for friable coal, and not for bituminous or other non-anthracitic coal.

† The new workings of the Westport-Stockton Company are in the Matipo seam, a lower split from the Millerton or Mangatini seam. See pp. 35, 157 *et seq.*

The outstanding feature of the Westport coal as mined is its lowness in ash. Some is of wonderful purity, leaving when burned little over ¼ per cent. of earthy matter. In the Millerton Colliery faces of coal showing not the slightest sign of a dirt band or parting and analysing under ½ per cent. of ash are quite common. In some localities, on the other hand, dirt, shale, or sandstone bands in the coal are plentiful, but only comparatively rarely is the intervening coal of impure character. In those cases where coal passes into shale what takes place is mainly a thinning of the coal-seam, accompanied by a corresponding thickening of the overlying and underlying shale.

Ultimate Analyses.—The only ultimate analysis of Westport bituminous coal found by the writers in the available literature is the following, made by Skey.* With it is quoted an analysis of Greymouth coal made in the Dominion Laboratory under the direction of J. S. Maclaurin† :—

	(1.)	(2.)
Carbon	77·34	78·41
Hydrogen	5·34	4·94
Nitrogen	1·73	0·87
Oxygen	8·04	7·86
Sulphur	0·51	2·35
Water	0·81	..
Ash	6·23	5·57
	100·00	100·00

The proximate analyses of these coals are as follows :—

	(1.)	(2.)
Fixed carbon	60·20	57·16
Volatile hydrocarbons	32·76	36·93
Water	0·81	0·34
Ash	6·23	5·57
	100·00	100·00

(1.) From Coalbrookdale.
(2.) From St. Kilda section, Brunner Mine.

The following ultimate analyses of Westport coals have recently been made in the Dominion Laboratory :—

	(1.)	(2.)	(3.)	(4.)	(5.)
Carbon	71·80	72·25	63·89	78·95	79·64
Hydrogen	5·82	6·06	5·07	5·50	5·58
Nitrogen	0·73	0·56	0·66	0·80	1·20
Oxygen	14·61	14·30	10·50	8·35	9·84
Sulphur	5·03	4·92	3·97	5·35	2·31
Ash	2·01	1·91	15·91	1·05	1·43
Totals	100·00	100·00	100·00	100·00	100·00
Calorific value, calculated from the analyses	7,293	7,419	6,548	8,036	7,996

* Lab. Rep. No. 30, 1897, p. 9.
† N.Z.G.S. Bull. No. 13, 1911, p. 118.

The proximate analyses of these fuels are as follows:—

	(1.)	(2.)	(3.)	(4.)	(5.)
Fixed carbon ..	50·68	50·87	45·54	60·87	59·72
Volatile hydrocarbons ..	42·01	42·14	36·41	37·37	38·11
Water	5·30	5·08	2·14	0·71	0·74
Ash	2·01	1·91	15·91	1·05	1·43
Totals ..	100·00	100·00	100·00	100·00	100·00
Total sulphur ..	5·03	4·92	3·97	5·35	2·31
Calories per gram from calorimeter	7,360	7,448	6,627	8,285	8,196
B.t.u. per lb. ..	13,248	13,406	11,929	14,913	14,753
Specific gravity ..	1·278	1·270	1·323	n.d.	n.d.

(1.) Seddonville State Colliery. General sample from mine (per Mr. I. A. James), June, 1914. Clean, fairly bright, hard coal.

(2.) Similar to (1). Somewhat brighter lustre.

(3.) Average sample from No. 1 bore, Charming Creek (per Mr. James). See also pages 139, 150.

(4.) Millerton Mine, from a working face. Sample forwarded by the Inspector of Mines (Mr. J. Newton).

(5.) Whareatea section of Coalbrookdale Mine, from a working face. Sample forwarded by the Inspector of Mines.

If recalculated on an ash-free basis the ultimate analyses become,—

	(1.)	(2.)	(3.)	(4.)	(5.)
Carbon	73·27	73·65	75·98	79·79	80·80
Hydrogen	5·94	6·18	6·03	5·56	5·66
Nitrogen	0·75	0·57	0·78	0·81	1·22
Oxygen	14·91	14·58	12·49	8·44	9·98
Sulphur	5·13	5·02	4·72	5·40	2·34
Totals	100·00	100·00	100·00	100·00	100·00

The presence of small amounts of phosphorus and arsenic in the bituminous coals is indicated by the coke analyses quoted on page 171.

Proximate Analyses.—During the past forty years or more several hundred analyses of Westport coal have been made in the Dominion Laboratory. The most representative of these are those made for the Admiralty, each of which as a rule represents a cargo of coal. The average of fifty-two* such samples of coal from the Denniston Mines, taken in 1908, 1909, and 1910, is as follows:—

Fixed carbon	56·16
Volatile hydrocarbons	39·37
Water	2·61
Ash	1·86
	100·00
Total sulphur per cent.	1·66

* One or two analyses with slight clerical errors have been included, whilst several with larger errors or in some other way doubtful have been excluded.

The average of forty-eight* similar samples of Millerton Colliery coal is:—

Fixed carbon	59·91
Volatile hydrocarbons	37·72
Water	0·96
Ash	1·41
	100·00
Total sulphur per cent.	3·42

The fixed carbon in the fifty-two samples of Denniston coal varies from 54·76 per cent. to 58·02 per cent., the volatile hydrocarbons from 37·56 to 40·84, the water from 1·27 to 3·62, the ash from 0·80 to 4·42, and the sulphur from 0·97 to 2·94. The corresponding figures for the forty-eight samples of Millerton coal are 56·48 and 63·30; 34·93 and 40·17; 0·52 and 2·21; 0·45 and 2·92; 2·11 and 6·11. Analyses of the crushed coal from Waimangaroa and other places show higher fixed carbon with correspondingly lower volatile hydrocarbons (see analyses quoted later), but such coal is not representative of the field as a whole.

The following table contains forty proximate analyses, selected from published reports as representative of the various sections of the Westport coalfield. A further series of analyses will be given in connection with the detailed descriptions of outcrops on later pages. It should be noted that Skey's results, partly owing to most of his samples being from outcrops, and partly owing to slight differences in the method of making the proximate analyses, show a higher percentage of fixed carbon than Maclaurin's. The average composition of Denniston-Coalbrookdale coal may be considered as represented by analysis No. 12, and similarly analysis No. 31 represents the average Millerton Colliery coal.

Analyses of Coal from Westport District.

Number.	Locality.	Fixed Carbon.	Volatile Hydro-carbon.	Water.	Ash.	Sulphur.	Remarks.
1	Coalbrookdale	65·45	31·55	2·60	0·40	1·20	From 9 ft. to 10 ft. seam; coal pitch-black, lustrous, puffs slightly; specific gravity 1·244; coke dull, coherent; ash dark-buff.
2	"	57·20	40·20	1·80	0·80	..	Coal glistening on some of cleavages, rhombohedral fracture; coke very porous, semi-metallic; ash light-buff.
3	"	62·70	31·55	1·05	4·70	1·85	Dull-black coal, tolerably hard and compact; specific gravity 1·250; coke semi-metallic in lustre, very porous, possessing little coherence.
4	"	58·74	35·97	0·70	4·55	..	Analysis as given sums to 99·96. Coke is given (erroneously) as 67·84 per cent. Rather friable coal, with brilliant lustre and conchoidal fracture; puffs to a hollowed ball; specific gravity 1·260; coke semi-metallic; ash white.
5	"	74·83	20·50	1·16	3·51	..	Sample submitted by Railway Department as "best." Coal lustrous, tender, puffs much; ash grey.
6	"	70·00	22·15	2·52	5·33	..	Sample submitted by Railway Department as "worst." Coal lustrous, compact; coke compact; ash grey.
7	"Banbury"	69·97	25·71	0·99	3·33	..	Sample submitted by Railway Department. Coal lustrous; puffs much.

* See footnote on preceding page.

ANALYSES OF COAL FROM WESTPORT DISTRICT—*continued.*

Number.	Locality.	Fixed Carbon.	Volatile Hydro-carbon.	Water.	Ash.	Sulphur.	Remarks.
8	Westport Company's Mine	61·75	34·20	2·53	1·54	..	Sample collected by Dr. Hector [probably from Banbury Mine]. Sum of analysis as given 100·02.
9	Ironbridge Mine, Kiwi district	57·36	39·61	1·55	1·48	2·18	Seam 12 ft. thick. Coal softens and intumesces on heating; coke hard and rather dense; ash light- to dark-brown, very granular. Calories 8,230.
10	Ironbridge Mine, Dundee Dip district	56·62	38·40	4·30	0·68	0·56	Seam 14 ft. to 25 ft. thick. Coal, &c., as for No. 8. Calories 7,762.
11	Coalbrookdale Mine, Munzie's section	55·7[illegible]	40·08	2·37	1·82	0·55	Seam 10 ft. to 12 ft. Hard dense coke; ash brown and granular. Calories 7,923.
12	Coalbrookdale Mine, Cascade section	58·75	37·24	3·61	0·40	1·74	Seam 20 ft. to 25 ft. Hard dense coke; ash brown and granular. Calories 7,708.
13	Denniston Collieries ..	56·16	39·37	2·61	1·86	1·66	Average of fifty-two analyses of Admiralty cargoes, made by Dominion Laboratory in 1908, 1909, and 1910.
14	Ground of Roche and party, Waimangaroa	87·09	10·95	0·64	1·32	..	Described by analyst as "highly metamorphic coal." Sample collected by W. M. Cooper.
15	(?)	89·01	2·60	3·21	5·18	..	Named "anthracite" by analyst. Sample collected by W. M. Cooper.
16	Sim's Spur	70·02	25·79	1·86	2·33	..	Named "bituminous coal" by analyst. Sample collected by W. M. Cooper.
17	Waimangaroa	79·43	15·22	4·21	1·14	..	Coal very incoherent. Coke very vesicular and has little coherence.
18	Waimangaroa (?) ..	64·31	33·33	0·99	1·37	..	From "eastern drive, 67 ft. in." Seam 5 ft. thick. Coal highly lustrous, homogeneous, unlaminated; swells very much, giving fragile coke.
19	Waimangaroa (?) ..	52·35	27·86	1·76	18·03	..	From "western drive, 20·2 ft. in." Seam 3¼ ft. thick. Coal somewhat tender, has little lustre and is laminated; coke close-textured, very coherent.
20	Waimangaroa basin ..	59·96	31·75	5·20	3·09	..	Average of seven early analyses (Skey). Errors in figures as printed are distributed.
21	Crane's Cliff, Ngakawau	76·71	19·86	2·12	1·31	..	Collected by James Park. Very tender coal; coke remarkably light and vesicular.
22	Marshall's lease, Ngakawau	62·43	25·58	8·20	3·79	..	Hard, coherent coal, caking strongly.
23	Ditto	49·01	35·94	4·83	10·22	..	" " "
24	"	60·43	28·36	8·82	2·39	..	" " "
25	"	59·61	27·90	10·23	2·26	..	Hard, coherent coal; frits, but does not cake.
26	Ngakawau Basin ..	62·76	30·35	4·63	2·26	..	Average of seven early analyses by Skey.
27	Westport-Stockton lease, D tunnel	58·50	39·98	1·34	0·18	4·52	Seam 14 ft. to 20 ft. thick. Coal swells moderately on heating and gives firm bright coke; ash dark-brown, pulverulent. Calories 8,183.
28	Westport-Stockton lease, south-east outcrop	55·04	41·39	2·49	1·08	4·09	Seam 16 ft. to 25 ft. thick. Coal, &c., as in No. 27. Calories 7,872.
29	Millerton Colliery, East district, Mine Creek	57·67	41·14	0·91	0·28	4·62	Seam 20 ft. thick. Coal swells very much, and gives hard porous coke; ash light-brown to grey; pulverulent. Calories 8,227.
30	Millerton Colliery, West district, Mine Creek	60·50	34·39	0·83	4·28	3·92	Seam 20 ft. thick. Coal, &c., as in No. 29. Calories 8,135.
31	Millerton Colliery ..	59·91	37·72	0·96	1·41	3·53	Average of forty-eight analyses of Admiralty cargoes, made by Dominion Laboratory in 1908, 1909, and 1910.

ANALYSES OF COAL FROM WESTPORT DISTRICT—*continued.*

Number.	Locality.	Fixed Carbon.	Volatile Hydro-carbon.	Water.	Ash.	Sulphur.	Remarks.
32	Seaton's lease, Mokihinui	55·43	38·38	4·67	1·52	..	Collected by W. M. Cooper.
33	Mokihinui	56·01	37·17	2·60	4·22	..	Forwarded by E. J. O'Conor, M.H.R. Moderately hard, highly lustrous coal; puffs greatly, yielding very porous and fragile coke; ash grey.
34	.. .. ..	56·67	35·88	4·03	3·42	..	Average of seventeen analyses by Skey.
35	Seddonville State Colliery, near Chasm Creek bridge	51·12	42·24	4·36	2·28	4·94	Seam 8 ft. thick. Coal yields a hard dense coke without much swelling; ash dark-brown, granular. Calories 7,402.
36	Seddonville State Colliery, Grant's face	52·27	41·20	4·65	1·88	4·99	Seam 20 ft. thick. Coal, &c., as in No. 35. Calories 7,354.
37	"Extension district," south of Chasm Creek, Seddonville State Colliery	52·30	40·08	4·70	2·92	3·91	Swells, forming a hard coke that burns to a brown ash. Calories 7,808.
38	Seddonville State Colliery	48·59	43·15	4·84	3·42	4·44	Swells, forming a hard coke that burns to a grey flocculent ash. Calories 7,673.
39	Cave area, Seddonville State Colliery	52·00	40·41	5·62	1·97	3·30	Swells, forming a hard coke; burns to a grey ash. Calories 7,328.
40	"Orikaka country" ..	50·96	36·68	4·33	8·03	..	Collected by W. M. Cooper [probably in Blackburn area].

References.

1–4. J. Hector: "First General Report on the Coal-deposits of New Zealand," 1866 (this is G.S. Rep. No. 1), pp. 30, 31, 33. Analyses probably by W. Skey.

5–7. Lab. Rep. No. 23, 1889, pp. 45–46. Analyst, W. Skey.

8. Lab. Rep. No. 15, 1880, p. 26. Analyst, W. Skey.

9–12. Lab. Rep. No. 40, 1907, p. 56. Analysts, Dr. J. S. Maclaurin and staff.

13. Lab. Rep. Nos. 42–44, 1909–11. Analysts, Dr. J. S. Maclaurin and staff.

14–16. Lab. Rep. No. 11, 1876, p. 13. Analyst, W. Skey.

17. Lab. Rep. No. 33, 1900, p. 7. Analyst, W. Skey.

18–19. Lab. Rep. No. 12, 1878, p. 21. Analyst, W. Skey.

The samples were forwarded by Mr. Fisher, and are possibly from the Fisher or Banbury Mine, Denniston. The locality given is Waimangaroa, however.

20. G.S. Rep. during 1874–76, No. 9, 1877, p. 25.

21. Lab. Rep. No. 22, 1887, p. 38. Analyst, W. Skey.

22–25. Lab. Rep. No. 31, 1898, p. 5. Analyst, W. Skey.

26. G.S. Rep. during 1874–76, No. 9, 1877, p. 25.

27–30. Lab. Rep. No. 40, 1907, p. 56. Analysts, Dr. Maclaurin and staff.

31. Lab. Rep. Nos. 42–44, 1909–11. Analysts, Dr. Maclaurin and staff.

32. Lab. Rep. No. 11, 1876, p. 13. Analyst, W. Skey.

33. Lab. Rep. No. 20, 1886, pp. 33, 60. Analyst, W. Skey.

34. Lab. Rep. No. 23, 1889, p. 49. Analyst, W. Skey. Water-percentage corrected.

35–36. Lab. Rep. No. 40, 1907, p. 57. Analysts, Dr. Maclaurin and staff.

37–38. Lab. Rep. No. 41, 1908, p. 10. Analysts, Dr. Maclaurin and staff.

39. Lab. Rep. No. 42, 1909, pp. 10–11. Analysts, Dr. Maclaurin and staff.

40. Lab. Rep. No. 11, 1876, p. 13. Analyst, W. Skey.

The following references to other analyses may be given:—

Lab. Rep. No. 8, 1873, pp. 13–14. Average analysis of Ngakawau coal.

Lab. Rep. No. 10, 1875, p. 11. Three analyses of coals from "Mount Rochfort district."

Lab. Rep. No. 11, 1876, pp. 11, 13. Analyses of nine samples of bituminous coal from various parts of Buller coalfield are given. Some of these are quoted in the table above.

Lab. Rep. No. 13, 1878, p. 21. Coal from Waimangaroa.

Lab. Rep. No. 15, 1880, p. 26. Coal from Wellington Mine, Waimangaroa.

Lab. Rep. No. 16, 1881, pp. 25, 26. Two analyses of coal from "Mount Rochfort," and one of coal from "the vicinity of Westport." The latter coal decrepitates in a lively manner.

Lab. Rep. No. 20, 1886, pp. 34–35. Three samples from Mokihinui.

Lab. Rep. No. 23, 1889, pp. 48–9. Analyses of sample No. 4672 given and 17 other analyses of coal from Mokihinui quoted. Slight errors or misprints appear in three of these.

Lab. Rep. No. 26, 1892, pp. 23, 24. Four samples from New Cardiff property; three from Mokihinui.

Lab. Rep. No. 28, 1894, p. 5. Sample from New Cardiff property.

Lab. Rep. No. 29, 1895, pp. 8, 9. Averages of seven samples from Ngakawau, and four from Coalbrookdale given, with comments.

Lab. Rep. No. 30, 1897, p. 8. Sample of coal from Westport, forwarded by Mr. F. G. Newman.

Lab. Rep. No. 33, 1900, p. 8. Sample from Cave area, New Cardiff (later Seddonville State Colliery).

Lab. Rep. No. 36, p. 4. Sample from Cave area, Seddonville State Colliery.

Lab. Rep. No. 37, 1904, p. 8. Twenty-nine analyses of coal from Denniston and Millerton mines (for the Admiralty).

Lab. Rep. No. 38, 1905, pp. 5, 7. Seventeen analyses of coal from Seddonville Colliery, and a large number (some giving sulphur only) of coal for the Admiralty.

Lab. Rep. Nos. 39, 1906, p. 7; 40, 1907, p. 12; 41, 1908, pp. 14–15; 42, 1909, p. 15; 43, 1910, pp. 8–9; and 44, 1911, pp. 10–11, give results of numerous analyses made for the Admiralty.

Lab. Rep. No. 40, 1907, p. 9. Sample from Westport-Stockton property. The appendix to this report contains analyses of representative mine samples, some of which have already been quoted.

Lab. Rep. No. 44, 1911, p. 9. Sample No. 766 from south of Mount Rochfort was forwarded by Mr. John Hayes. Is high in fixed carbon.

Lab. Rep. No. 45, 1912, p. 13. Sample No. 707, from south of Mount Rochfort is high in fixed carbon.

Lab. Rep. No. 46, 1913, p. 12. Sample No. 286 is presumably from Westport-Stockton lease. Other analyses are quoted elsewhere in this bulletin.

Lab. Rep. No. 47, 1914, p. 16. Three analyses of samples from Cascade Creek, forwarded by Mr. J. H. Shackleton. Other analyses are quoted.

Cox, S. H.: "Notes on the Mineralogy of New Zealand," Trans., vol. xv, 1883, p. 373. An average analysis of Westport bituminous coal and one of the crushed coal are given.

W. P. Evans: "Analyses (Technical) of New Zealand Coals." Trans., vol. xxxi, 1899, p. 564. Analyses of Coalbrookdale, Granity Creek, and Westport-Cardiff (2) coals are given.

The table on the next page contains analyses of various samples collected during the course of the geological survey in the years 1911–13. Nos. 3, 4, 7, and 8 were obtained through the courtesy of Mr. I. A. James, formerly manager of the Seddonville State Colliery, and now manager of the State Coal-mines, Greymouth.

Sulphur.—As already remarked, the sulphur-content of the bituminous coal increases markedly from south to north. The sulphur is irregularly distributed in the coal, and a systematic investigation of this matter would yield some interesting results. Although

ANALYSES OF SAMPLES COLLECTED DURING COURSE OF GEOLOGICAL SURVEY.

Number.	Locality, &c.	Fixed Carbon.	Volatile Hydro-carbon.	Water.	Ash.	Total Sulphur per Cent.	Calories per Gram by Calorimeter.	British Thermal Units per Pound.	Remarks.
1	Chasm Creek, above Yellow Silver-pine Exploration Company's bridge	48·28	46·35	3·05	2·32	4·67	7,613	13,703	From upper 2½ ft. of outcrops on bank of creek. Swells, forming hard coke; ash, dark-brown.
2	Ridge in "Patten's lease," south-west of Chasm Creek	52·08	43·60	3·10	1·22	7·26	7,382	13,288	From trench at height of 915 ft. showing 7 ft. of coal. Swells, forming hard coke; ash, light-brown.
3	Bridge section, Cardiff Mine ..	54·95	39·13	3·66	2·26	1·34	7,617	13,711	From old working-face. Forms compact coke.
4	South of Bridge section, Cardiff Mine	46·67	38·80.	3·52	11·01	6·04	6,942	12,496	From 4½ ft. outcrop. Forms compact coke.
5	Seddonville State Colliery	50·77	42·08	5·19	1·96	4·98	7,404	13,327	Average of two samples. Ultimate and proximate analyses quoted on pages 133–34. Specific gravities, 1·278 and 1·270.
6	Upper seam, Charming Creek ..	49·22	46·59	1·74	2·45	5·73	..	..	From 2 ft. outcrop in creek, below No. 1 bore. Forms dense hard coke; ash, grey.
7	Main seam, No. 1 bore, Charming Creek	45·54	36·41	2·14	15·91	3·97	6,627	11,929	Some shale with sample. Ultimate analysis on page 133. Specific gravity, 1·323.
8	Main seam, No. 8 bore, Charming Creek	46·58	39·56	2·07	11·79	4·68	..	..	Probably some shale with sample. Specific gravity, 1·339.
9	Coal Island, head of Blackburn ..	56·99	36·77	5·72	0·52	0·91	..	..	From outcrop 25 ft. or more thick. Does not coke; ash dark-brown.
10	Head of Blackburn pakihi ..	53·05	40·50	3·13	3·32	2·45	..	..	Outcrop coal. Forms a firm coke; ash, grey.
11	Tiger pakihi, near Mackley River ..	51·52	38·02	9·25	1·21	3·99	6,419	11,514	From short drive in 11 ft. outcrop. Frits, but does not cake; ash, light-brown.
12	Mackley River, above Mossy Creek junction	45·73	41·36	5·24	7·67	4·44	..	..	From 3½ ft. seam on bank. Forms dense hard coke; ash, grey.
13	Granity Creek	63·85	32·69	0·61	2·85	4·22	..	..	From thick outcrop in creek gorge. Swells, forming hard coke; ash, dark-brown.
14	Granity Creek	62·45	36·39	0·66	0·50	6·21	..	..	From upper 6 ft. of outcrop in creek gorge, about 1,750 ft. above sea-level. Swells, forming hard coke; ash, dark-brown.
15	Near T 35 Creek, half-mile south-east of trig. A.H.	50·33	41·21	2·67	5·79	4·02	7,261	13,070	From thick outcrop.
16	Near junction of Billo and Deep creeks	58·50	34·34	6·42	0·74	1·88	6,990	12,582	From 8 ft. outcrop.
17	Coal island, east of Darcy Creek ..	54·34	39·53	5·50	0·63	2·96	7,228	13,010	From thick outcrop. Forms a firm coke; ash, dark-brown.
18	Head of Erin Creek, east of Mount William Range	51·24	40·89	4·82	3·05	4·62	..	..	From thick outcrop. Forms a coke, but does not swell; ash, dark-brown.
19	Moran's water-race, near Addison's..	73·45	21·96	1·51	3·08	5·66	8,056	14,501	Weathered and crushed coal. Forms a firm coke.

in places iron-bisulphide (pyrite or marcasite) concretions and shells—the "brasses" of the miner—are plentiful, the greater part of the sulphur is evidently combined with hydrogen or hydrocarbons, and not with iron or other metal. This is especially the case with the coals from the northern part of the field, which may contain from 4 to 6 per cent. of sulphur, together with a very low ash. The following data are of interest in this connection: The Admiralty cargoes of Denniston coal in 1908 contained on an average 1·69 per cent. of sulphur; in 1909, 1·71 per cent.; in 1910, 1·85 per cent., and in 1911, 1·59 per cent. The corresponding percentages for Millerton coal are 4·52, 4·16, 3·27, and 3·17 per cent. The average sulphur-content of eight samples of Seddonville State Colliery coal, analysed in the Dominion Laboratory, is 4·31 per cent., with a range of 3·30 to 4·99. Two analyses of Westport-Cardiff coal, made by W. P. Evans, show only 0·54 and 0·87 per cent. respectively,* whilst one of a single lump from the Bridge section gives 1·34 per cent. (see table on page 139). Since the coal of the same seam in adjoining areas is almost uniformly much higher in sulphur, it is probable that Dr. Evans's samples were not representative of the run-of-mine coal.

Dr. Evans observed that Westport-Cardiff coal, when pulverized, gave off sulphuretted hydrogen at ordinary temperatures, a phenomenon which, so far as he could find, had not previously been recorded as happening with a hard bituminous coal.† The same chemist, however, had previously found that Blackball coal gives off great quantities of the gas at a temperature of 190°.‡ One of the present writers, many years ago, noted evidence of sulphuretted hydrogen at a small fault in a coal-mine near Green Island, Otago, and, as stated on a later page, Charleston lignite during distillation emits this gas.

In view of the highly poisonous nature of sulphuretted hydrogen, attention may here be called to the possibility of its evolution in dangerous quantity in some New Zealand collieries, especially when coal is heating in the workings.

Inflammability of Dust.

As regards inflammability when in a powdered condition, the bituminous coals of the Westport district are believed to present much the same characters as similar coals from other parts of the world. The mine workings are in general damp and cool, and as a rule the air circulating through them is almost saturated with moisture. Partly for these reasons, perhaps, no dust-explosion or gas-explosion intensified by dust has ever occurred in the Westport mines.

At the time of writing experiments are being made in the Dominion Laboratory with a view to obtaining approximate quantitative determinations of the degree of inflammability possessed by coal-dust from the Westport and other New Zealand mines.

Influence of Weathering on Composition and Physical Characters.

Outcrop coal, if not too much exposed to sun and weather, is generally harder than the material mined two or three chains away under cover. Theoretically it ought to be somewhat higher in fixed carbon, owing to the escape of volatile constituents, but the rule seems to have exceptions, and some highly weathered outcrop coal, consisting of small cuboidal pieces, differs little in proximate composition from the run-of-mine fuel. The following analyses may be quoted:—

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* "Analyses (Technical) of New Zealand Coals." Trans., vol. xxxi, 1899, p. 564.

† On the Apparent Occlusion of Sulphuretted Hydrogen in a Bituminous Coal." Trans., vol. xxxi, 1899, pp. 566–67.

‡ "On the Distillation Products of Blackball Coal." Trans., vol. xxx, 1898, p. 489. See also vol. xxxi, pp. 556–57. Reference to this paper was unfortunately omitted from N.Z.G.S. Bull. No. 13 (Greymouth).

	(1.)	(2.)	(3.)
Fixed carbon	51·95	53·58	60·70
Volatile hydrocarbons	43·65	40·58	30·56
Water	3·18	2·77	7·32
Ash	1·22	3·07	1·42
	100·00	100·00	100·00
Total sulphur	2·41	1·19	2·64

Nos. 1 and 2 give a hard coke; No. 3 is non-coking.

No. 1. Highly weathered coal, collected on surface near W. M. Cooper's station L 100, Upper Waimangaroa (north of Kiwi Compressor).

No. 2. Weathered coal from outcrop without cover, north of Westport-Stockton Company's peg XII.

No. 3. Outcrop coal from 6 ft. seam east of Upper Granity Creek.

From these analyses it would appear that prolonged weathering alone in a wet temperate climate does not remove much volatile hydrocarbon, nor apparently does it introduce much water into an air-dried sample, unless the coal is in a constantly damp or wet situation, like the outcrop that furnished No. 3 sample. Many of the analyses quoted on later pages are of outcrop, and therefore somewhat weathered coal, but no marked change in composition appears to have taken place through exposure. The matter is one that deserves careful investigation, for the generally accepted views on the subject apparently require considerable modification.

Origin of Bituminous Coal.

The evidence bearing on the origin of the bituminous coal-seams obtained during the survey of the Westport district as a whole favours the "drift theory" rather than the "growth-*in-situ* theory." The principal reasons for coming to this conclusion are those that follow:—

1. Nothing corresponding to a true soil can be observed beneath the numerous outcrops of coal, nor have roots of any kind been seen in the floor of any seam. In many places the coal rests upon a dark carbonaceous shale which passes within three or four inches into bluish shale, practically devoid of vegetable remains. In other places the coal rests upon a very thin shaly layer, and this upon light-coloured sandstone or grit. Although there is not the slightest evidence of any true surface soil having ever existed beneath the Westport coal-seams, the reader may be reminded that this condition is not inconsistent with some of the more modern forms of the growth-*in-situ* theory, which regard the original vegetable matter as having accumulated under water, and repudiate the explanation of underclays as representing old soils, a supposition, however, which is "no doubt the chief prop of the *in situ* theory."*

2. The general appearance of the strata that immediately enclose the coal-seams, and of the shale or sandstone bands within the seams themselves, strongly suggests that the substance of the coal itself, as well as the enclosing beds and the contained shale, &c., is water-borne. It is hardly possible to state evidence of this kind without long descriptions of the field occurrences, but the chief facts pointing in the direction indicated are the gradual passages of coal into shale through the seam thinning whilst roof and floor shale thicken and approach; the manner in which seams

* E. A. Newell Arber: "The Natural History of Coal," 1911, p. 91.

split;* the highly lenticular nature of the thicker deposits of coal; the manner in which coal-seams thin out against ancient islands of the pre-Tertiary rocks; the false bedding of the underlying and overlying sandstones and grits, which indicates the prevalence of strong currents capable of transporting and sorting vegetable material, &c. Figs. 4, 9A, 9C, 12A–E, 14, 15B, 16A, 16B, and others illustrate some of these conditions (see end of volume).

3. The peculiar occurrences known as "doughboys" (see page 179) are perhaps more easily explained by the drift theory than by the growth-*in-situ* hypothesis.

4. The resin present in the Coalbrookdale and Seddonville coal supports the drift theory, for it must almost certainly have been transported by water either as separate lumps or embedded in floating trees.

5. The purity of most coal has often been adduced as an argument against the drift theory, and, according to Newell Arber, rightly so.† Yet, as Arber also points out, this consideration need not rule the drift theory out of court in every case. Water-sorting is quite competent to produce an accumulation of pure vegetable matter, and in the Westport district the coal in many places is so extremely free from ash that the slow accumulation of the original vegetable matter *in situ* without some sorting action to remove extraneous material appears impossible.

The only variation of the growth-*in-situ* theory which is not inconsistent with the facts observed in the Westport district is that which supposes the coal-forming vegetation to have been fast-growing water-plants, probably gelatinous algæ. Even if this view be adopted, the presence of resin implies transportation of part of the material.

Circumstances have not permitted the writers to devote much attention to the study of the field evidence bearing on the origin of the Westport coal. The district, however, offers remarkable facilities for such a study, the natural sections of the coal-seams and adjoining strata being almost unrivalled elsewhere. The Greymouth district also affords similar sections, but forest obscures the coal-bearing strata to a greater extent than near Westport, and the country is more uneven in relief. With these New Zealand districts may be compared the Commentry coalfield in central France, which also is remarkable for its exposures of coal-seams and associated strata. Noteworthy is the fact that here also the field evidence is strongly in favour of the drift theory.‡

It may perhaps be as well to caution the New Zealand student against any complete acceptance of either the drift or the growth-*in-situ* theory. Both, doubtless, are true under some conditions, and in some cases both theories may apply to the one deposit. For a discussion of the whole subject the reader may be referred to the little book by Newell Arber already cited, and to the literature listed therein.

Detailed Description of Outcrops, &c.

(1.) *Seddonville-Mokihinui District.*—Two coal-seams are developed in the neighbourhood of Seddonville, the lower of which, the main or Seddonville seam, varies from a few inches to 25 ft. or more in thickness. The upper seam occurs about 50 ft. above the lower, and as observed is from 10 in. to 25 ft. in thickness. So far as known all the mine-workings are on the lower seam, but the coal worked near Coal or Parenga Creek (Mokihinui Mine) perhaps belongs to the upper seam, here locally thickened.

* As shown by figs. 12A–E these splits in the Westport district are not to be explained by local tilting of the ground as suggested by Newell Arber (*op. cit.*, p. 113).

† *Op. cit.*, p. 87.

‡ Newell Arber, *op. cit.*, pp. 127–29.

The main seam in this locality varies from 4 ft. or 5 ft. to 30 ft. in thickness, and for the sake of distinction may be called the Hut seam, a name applied by Hector to a portion of it.

Owing to the greater part of the coal-bearing ground near Seddonville (together with a considerable area of nearly barren ground) being included in a State coal reserve, the outcrops will be described with a considerable amount of detail.

On the north side of the Mokihinui River, where are several square miles of Eocene strata, coal is exposed only at the point on the river-bank where the old workings of Garvin and Batty are situated. The outcrop, which is almost at sea-level, appears to be not more than 5 ft. in thickness* and to have a moderate dip to the north-east. Directly opposite this outcrop fragments of coal occur on the surface near the railway-line and the road, but no outcrop is visible, although old drifts, now collapsed, indicate that coal has here been worked. One of these drifts, a heading, was driven in 1885 by the old Mokihinui Coal Company. The seam, at first 6 ft. thick, thinned, and at 10 chains was wholly replaced by shale. A shaft on the line of the heading at 20 chains from its mouth failed to find coal, but a thin seam is exposed on both sides of a gully another 12 chains to the southward.† In describing what is probably the same locality, McKay‡ gives full particulars, which, however, differ somewhat from the information supplied to the writers. The piles of the railway-bridge across Chasm Creek are said to have been driven into a 7 ft. seam of coal, a statement which could easily be verified by boring. Between this creek and Page Creek, a seam of hard bright coal from 2½ ft. to 5 ft. thick, doubtless the same as that seen across the river, outcrops at several points, and has been worked by means of adits, which may still be entered for short distances. The roof is sandstone, and the floor consists of a thin underclay, followed by sandstone or grit. At a very old adit (possibly that said to have been driven by James Burnett) about 4 chains up Chasm Creek above the road-crossing the strike is about 256°, and the dip 6° to west of north. Elsewhere the observed strikes vary from 261° to 302°, and the dips from 8° to 15° to the northward or north-eastward. An upper seam, 10 in. thick, enclosed in sandstone, appears on a track immediately above the Chasm Creek bridge. R. B. Denniston gives several sections (Nos. 190 to 192) of coal-bearing strata in the neighbourhood of Chasm Creek.§ South-south-westward from the old workings the coal like that in the old Mokihinui Company's heading, apparently thins out, for it cannot be traced up Chasm Creek. Half a mile southward, however, a small coal-bearing area was worked by the Westport-Cardiff Coal Company. At the entrance to the workings the coal is at least 10 ft. thick, and, though in part somewhat friable, is clean and of good quality. The roof consists of several feet of carbonaceous shale with many leaf-remains, striking almost due north, and dipping at 10° to the eastward. Not many chains to the south are the main Westport-Cardiff workings, now devastated by fire.

On a spur that trends south-westward from Chasm Creek towards the head of Frank Brook and shows several coal-outcrops, the Mines Department during 1911 did a considerable amount of surface prospecting. At a barometric height of 545 ft. a trench shows 1 ft. or a little more of coal, overlain by several feet of shale with

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* Hector reports 6 ft. (Rep. G.S. during 1871–72, No. 7, 1872, p. 141). The coal in Garvin's shaft is said to be 5 ft. thick.

† Information obtained chiefly from Mr. Frank Reed, Inspecting Engineer, Mines Department, who in 1885 was manager for the Mokihinui Coal Company.

‡ "On the Mokihinui Coalfield." Rep. G.S. during 1886–87, No. 18, 1892, pp. 162–64.

§ Detailed Notes on the Buller Coalfield," Rep. G.S. No. 9, 1877, p. 171. The Page's Creek of Denniston is not the tributary of Chasm Creek, now known by that name, but Chasm Creek itself. Denniston's section No. 189 ("Seaton's drive") probably refers to the same locality.

thin coaly layers, above which is 1 ft. of coal, with a dark micaceous sandstone as roof. To the southward are other outcrops of poor and thin coal. At a height of 560 ft. the following section is seen in a trench: Dark shale overlain in order by 2½ ft. of friable coal, 2 ft. of dark shale, 2 ft. of weathered coal, 4 in. or 5 in. of carbonaceous sandstone, and finally a coarse sandstone or grit (see Fig. 3A). The strike is approximately 256°, the dip 6° to east of south. At a height of 615 ft., at least 8 ft. of good but somewhat friable coal is seen at a small waterfall on the north side of the ridge. The roof consists of 10 in. of shaly sandstone, followed by sandstone and grit, striking 261°, and dipping at 8° to the southward (see Fig. 3B). At a height of 915 ft. about 7 ft. of somewhat tender coal is exposed by a trench. Except for a small dirt-band 18 in. from the floor, the coal is clean. The floor of the seam is shale, and the roof is dark sandstone, striking 258°, and dipping 15° to the east of south. An analysis of a representative sample of the coal is given on page 139 (No. 2).

Nine chains west of the last-mentioned outcrop is 5½ ft. of hard but somewhat impure coal, whilst 12 to 14 chains south-westward, at a height of 855 ft., an outcrop of coal, 6 ft. to 6½ ft. thick, is seen under a small waterfall. The upper 2 ft. consists of good hard coal, but the lower 4 ft. or more is in part friable, and in part impure "bony" or "splint" coal. The floor is not clearly observable, but fine-grained dark sandstone passing downwards into a gritty rock appears a little below the coal. The roof is sandstone, fine-grained for the first foot, striking 280°, and having a southerly dip of 10°. A small fault with downthrow to the eastward is visible in the section exposed.

The dips and strikes of the strata when plotted show that more than one fault with upthrow to the southward must traverse the area containing the outcrops just described. The narrowness of the ridge and the thinness or poor quality of several of the outcrops leave little hope that the coal can be profitably extracted under present-day conditions. The workable area is probably not more than 18 or 20 acres. Not far to the southward, however, is the Bridge section of the Westport-Cardiff Mine.

Almost continuous outcrops of coal are visible on both sides of Chasm Creek gorge from a mile and a quarter to nearly three miles above the mouth of the stream. The outcrop coal on the eastern side is almost everywhere of good quality, and is thin only between the Cave and Grant's Face sections of the State mine. Elsewhere it is from 8 ft. to 25 ft. thick. The coal has been extensively worked by the Westport-Cardiff Company (Hector section) and by the State, but unfortunately in the workings it is not so good as promised by the outcrops, though the thickness is well maintained. In particular, much is friable, and therefore has not been extracted to any great extent. Several faults of varying throw traverse the coal-bearing area, and have tended to prevent it from being economically mined.

On the western side of Chasm Creek the coal varies greatly in thickness and quality. In the Bridge section of the Westport-Cardiff Mine the outcrop is over 20 ft. thick, and in the workings a similar thickness seems to be maintained. The coal, though in places friable, especially near rolls, is usually hard, and in general is of fair to good quality. The faces, many of which are still accessible, show one or two small dirt-bands, and a few cracks filled with sandstone. "Rolls" and small faults or "troubles" are somewhat common. To the north-west of the Bridge section the coal is cut off by a deep gully, whilst to the south there is a large fault, with upthrow in that direction, so that the workable area is limited to a comparatively small triangular patch, and any adjoining coal would have to be worked as a separate section. Southward from the fault mentioned above, 20 ft. or more of decidedly poor coal outcrops for several chains. The seam contains several dirt or shale bands, but improves southward, until about 10 chains from the first break a second fault with a southerly upthrow of 180 ft. or more cuts it off. The next outcrop, at a barometric height of 610 ft., shows only 4½ ft. of dirty friable coal. An analysis of this is given in the table on page 139 (No. 4). A quarter of a mile south of the last fault, at a point 750 ft. above sea-level, is 9 ft. of good though somewhat friable coal, dipping gently to the north-west. Immediately to the south-east is a considerable fault with downthrow in that direction. The outcrops of coal seen for the next mile, as disclosed by prospecting operations during the early part of 1911, are: (*a*) 3 ft. of good coal, followed upwards by 18 in. shale, 1 ft. splint coal, and 8 in. good coal; (*b*) 3 ft. 8 in. coal, of which only the top 14 in. or so is hard; (*c*) 4 ft. 4 in. coal, of which the upper 16 in. is good, the rest very poor and dirty; (*d*) 4 ft. coal (floor not seen); (*e*) 7 ft. coal, with shaly roof and floor; (*f*) 1 ft. to 2 ft. coal with shaly roof and sandstone floor; (*g*) small outcrop of natural coke (see page 171); (*h*) 18 ft. of good coal (Dove's drive); (*i*) 9 ft. coal, with 4 in. shale and dirt band near the top; (*j*) 8 ft. coal resting on 3 ft. of shale, underlain by 1 ft. to 1½ ft. coal (see Fig. 4); (*k*) over 9 ft. coal, with floor not seen (Bridge section of State mine); (*l*) 10 ft. coal underlain by 1 in. of shale and a further thickness of coal, with floor not seen (Bridge section of State Mine).

In the Seddonville State Colliery the coal as worked in the Cave and Grant's Face sections varied from less than 8 ft. to fully 25 ft. in thickness, and was usually from 14 ft. to 16 ft. thick. At the Chasm Creek mouth of the main tunnel (above the bridge), a 3 ft. to 4 ft. band of sandstone appears in the lower part of the seam. Opposite the bridge, a few chains to the westward, where the main haulage-line reaches Chasm Creek gorge, the coal is at least 15 ft. thick, and the sandstone band is apparently represented only by a thin shaly parting. Elsewhere there are small bands of sandstone and shale, but these did not cause much trouble in the working of the coal. In places there are narrow vertical fissures or cracks filled with sandstone, one or two of which are large enough to bring to mind the so-called "sandstone dykes" observed in some foreign localities. The singular occurrences known as "doughboys" are described elsewhere (page 179). Near any of the numerous rolls the coal usually becomes friable and dirty, then thins, and concurrently the floor rises. In places, the roof having sagged so as to approach the floor, the coal, being apparently squeezed to one side or the other, is reduced to a foot or two in thickness. Beyond the roll the seam assumes its ordinary thickness and quality. Most of the rolls are attended by a rise or drop of the seam, and are thus equivalent to faults, into which, as a matter of fact, many actually pass. Thus it is not always possible to distinguish between rolls and minor faults, both being expressions of movement affecting the coal-bearing strata.

To the south-west of the State mine Bridge section the ground has been hand-bored with unsatisfactory results. The coal thins to 7½ ft. in a few chains, and at a distance of little over a quarter of a mile completely disappears, apparently owing to an ancient ridge or island of granite rising above the level at which the coal vegetation was deposited.

All the coal outcrops in Chasm Creek hitherto mentioned belong to the lower or Seddonville seam, and are overlain by 50 ft. to 100 ft. of sandstone and grit containing minor shale-bands and the small upper coal-seam previously mentioned. Under the main seam comes a shale, bluish in colour except close to the coal, where it becomes black from admixture of carbonaceous material. Its thickness varies from a few inches to several feet. The shale is underlain by sandstone or grit, which passes into a pebble-bed or a conglomerate of no great thickness or prominence. This rests on granite, or, in places, hornfels of the Aorere Series.

The dip of the coal-measures near Seddonville, though almost everywhere moderate, is so irregular in direction that a verbal description is of little value, and only by large scale maps can it be clearly indicated. In general it is north-eastward, but in many localities it inclines to the southward. Faults determine the actual position of the coal to nearly as great an extent as its dip, and are in practice of more than equal importance in influencing the location of workings.

A few chains to the south-east of the Bridge section of the Seddonville Colliery coal is exposed in a trench at a height of 480 ft. or 500 ft. above sea-level. A few chains farther to the south-east 4 ft. of hard but apparently somewhat impure (splinty) coal resting on shale is seen in a rill gutter at a height of about 600 ft. The roof is not visible, and the seam is probably much thicker than 4 ft., for a trench only a chain away exposes at least 14 ft. of coal. A few chains to the south-east coal, underlain by sandstone, again outcrops, but the seam has been largely denuded, so that its original thickness cannot be ascertained. Apparently a fault with upthrow of over 100 ft. to the south-east separates the first outcrop at a height of 480 ft. from the other coal-outcrops, which presumably belong to the same seam, the Seddonville, but it is not certain that the identification holds good.

About 50 chains to the southward of the last-mentioned outcrop coal appears on the west bank of Chasm Creek, immediately south of the fault. Here from 5 ft. to 7 ft. of coal (floor of seam out of sight*) containing a 3 in. shale band is visible. Two chains up-stream the shale is 1 ft. 7 in. thick, with 1 ft. 8 in. coal above it and 2 ft. 10 in. below. A little farther up-stream the coal passes below water-level. The stone is here 4 ft. thick, whilst the top coal has dwindled to 1 ft. 3 in. Figs. 4A and 4B illustrate the section in this locality, which has also been described by R. B. Denniston. (See Section No. 185 of his report.†) An analysis of the top coal is given on page 139. The upper Chasm Creek coal, and an outcrop half a mile to the westward on the Yellow Silver-pine Exploration Company's tramway are almost directly overlain by dark marine sandstone, passing into mudstone, and may be correlated with the outcrops in Coal Creek valley described in the next paragraph as belonging to the Hut seam.

Half a mile from the terminus of the Seddonville-Mokihinui Mine railway-line, between the two bridges over Coal or Parenga Creek, a 1 ft. coal-seam outcrops on the steep slope to the eastward. The roof is grit, and the floor 2 ft. of shaly sandstone underlain by ordinary sandstone. These rocks dip gently to the north or north-west. Opposite the end of the railway coal over 8 ft. thick outcrops on the east side of Coal Creek. This is the so-called Hut seam, which outcrops for 6 chains or more up the stream, and is then cut off by a fault. Narrow workings extend on this seam for 600 ft. to the dip. The roof is sandstone, or in one place grit, and contains a thin coal-seam about 3 ft. above the main body. Twenty-five chains above the rail-head is the spot on the west side of Coal Creek where Sir James Hector saw a 32 ft. face of coal,‡ but this, through removal by working and through the ravages of fire, has disappeared. The extent of the fire is marked by 2 or 3 acres of half-bricked, tumbled masses of mudstone, with a few small steam-jets depositing sulphur and alum-like incrustations. Two or three chains above the point where the mine-entrance used to be a small outcrop of good, though somewhat friable, coal containing resin appears on the west bank of the creek at water-level. Eight or ten chains above this, roughly at 300 ft.§ above sea-level, 12 ft. or more of solid coal outcrops close to the creek. Its roof is a micaceous gritty mudstone, probably of marine origin. Fifteen chains to the southward 2 ft. of shale and impure coal, underlain by

* McKay (G.S. Rep. No. 21, 1892, p. 83) gives the thickness of the coal as 10 ft., but this is probably second-hand information.

† "Detailed Notes on the Buller Coalfield." Rep. G.S., No. 9, 1877, p. 170.

‡ "On the Mokihinui Coalfield." Rep. G.S. during 1886–87, No. 18, 1887, pp. 157 *et seq.*

§ This barometric height and many others ought perhaps to be slightly reduced, but no certain correction can be applied.

dark micaceous sandstone and overlain by grit, outcrops at 320 ft. above sea-level. The strike of the beds varies from north to north-north-east; the dip is 10° to the eastward. In his report of 1877 Denniston gives three sections seen on the banks of Coal Creek (Nos. 186 to 188, page 170).

In the valley of Cascade Creek, which enters Coal Creek near Mokihinui Mine Railway-station, are various outcrops of coal, averaging 5 ft. to 6 ft. in thickness. These were explored by the old Mokihinui Company and by co-operative parties of miners (see Chapter II) with unsatisfactory results, the coal being in many places friable or dirty. There are also several outcrops on the Yellow Silver-pine Exploration Company's tram-line in the same locality, one of which is illustrated by Fig. 5.

Though Hector and McKay consider that the 32 ft. seam is distinct from the Hut seam, which they correlated with a 7½ ft. seam said to have been found by boring 22½ ft. below the big seam, the various outcrops near Mokihinui Mine may well be regarded as belonging to one seam, which in places has a split. Unfortunately, the 32 ft. coal thins both to the southward and the north-westward. To the eastward the coal, owing to its dip, passes under an increasing cover of Kaiata mudstone. Probably it lives to the Glasgow fault, but only by actual exploration can its thickness and quality be determined. There is, however, much reason to fear that such coal as exists will be much disturbed by faulting.

The Seddonville-Mokihinui area, concerning which high hopes were once entertained, has been extensively tested by actual working during the past half-century. The results, as is well known, have been unsatisfactory, both to private persons and to the State, though, as may be pointed out, the profit obtained from the working of the railway and the promotion of settlement offset the mining losses to some extent. The coal-seams are remarkably variable in thickness and quality, whilst faulting of the measures offers considerable impediment to systematic development. Hence, under present conditions, there can be but little inducement to work the remaining known patches of coal, such as the Cardiff Bridge section. The Seddonville flats and an area east of Coal Creek are underlain at some depth by the coal-horizon. Boring, however, is needed in order to prove the presence or absence of workable coal. Again, on the north side of the Mokihinui River is a considerable extent of country underlain by coal-measures, and though these certainly thin out to the northward, there remains a possible coal-bearing territory of some size.

Analyses of Seddonville-Mokihinui coal are given in the table on page 137. Four analyses of samples collected during the recent geological survey are given on page 139, and a number of others will be found in the Colonial or Dominion Laboratory reports, and in old Geological Survey reports.*

(2.) *Charming Creek Area.*—On the precipitous north bank of the Ngakawau River, a few chains below its junction with Charming Creek, are two small irregular coaly seams, the outcrops of which may be reached by means of the tram-line from Watson's sawmill. The enclosing sandstone and grit strike about 344°, and dip at 10° to the north of east. To the northward, near the sawmill, and at a higher horizon, a 6 in. coal-seam, striking 264°, and dipping at 12° to the northward, outcrops on the west side of Charming Creek. East of the sawmill what may be the same seam is represented by 14 in. of coal outcropping on the southern bank of Charming Creek at a height of about 200 ft. above sea-level. The enclosing strata are gritty sandstones, above which comes sandy mudstone of marine origin (Kaiata beds). These rocks strike between 262° and 280°, and dip at 10° to 13° to the northward. For a mile and a half to the north-east only mudstone is seen in the bed of Charming Creek, but a

* See Rep. G.S. No. 18. 1887. p. 159; and Rep. G.S. No. 21, 1892, pp. 85, 94.

little below the junction of Rod Brook 9 in. of impure coal, striking 239° and dipping at 5° to the north-west, appears on the southern bank. The seam is enclosed in sandstone, passing upward into marine mudstone. East of the point where McKenzie Brook joins Charming Creek a coal-seam from 9 in. to 2 ft. thick outcrops at a number of places in or near the creek, at heights of from 400 ft. to 500 ft. above sea-level. One of the sections observed is illustrated by Fig. 6. From the maps it will be seen that the strike of the enclosing strata is variable, and that their dip varies from 3° to 15°. The maps also show a number of minor faults, several of which give rise to small waterfalls in Charming Creek. The small seam just mentioned corresponds in horizon to the upper seam at Seddonville, and therefore the Mines Department, a few years ago, drilled a series of boreholes in order to determine the existence or absence of a lower seam corresponding to that worked at Seddonville. In all, sixteen bores, the positions of which are shown on the maps, were drilled, with the result that a seam of good coal was found to underlie a portion of Charming Creek Valley. Some details of the bores are as follows:—

No. 1 bore (about one mile and a half south-west of Cave workings, Seddonville Mine), 114 ft. deep: At 39 ft. 6 in., 1 ft. 8 in. of coal (upper seam); at 91 ft., 17 ft. of hard coal followed by 3 ft. friable coal (lower or main seam). Analyses of the coal will be found at the end of this section.

No. 2 bore (north-east of No. 1), 315 ft. deep: Traces of coal at 183 ft.; 2 ft. 6 in. of coal at 190 ft. 2 in., followed by 8 in. of hard sandstone and 10 in. more of coal (probably lower seam).

No. 3 bore (near Watson's sawmill), 370 ft. deep: Reached gneiss, but found no coal. This result could have been predicted as probable from the geology of the neighbouring area.

No. 4 bore (north-east of No. 3), 525 ft. deep: Reached granite or gneiss, but found no coal. This result agrees with the geological indications.

No. 5 bore (west of No. 1), 95 ft. deep: At 35 ft., 2½ ft. coal (upper seam); at 75 ft., 20 ft. of coal (lower seam).

No. 6 bore (south of Charming Creek, near Reed Brook junction), 330 ft. deep: At 226 ft., 2 ft. 6 in. of coal (lower seam); gneiss from 315 ft. to bottom.

No. 7 bore (south-east of No. 1), 167 ft. deep: At 38 ft., 3 ft. coal and shale (upper seam). Main seam not found—has thinned out. Bottom of bore in coarse grit.

No. 8 bore (north-west of No. 1), 119 ft. deep: At 81 ft., 2 ft. 6 in. of friable dirty coal followed by 19 ft. 3 in. of hard coal (main seam); at 115 ft. gneiss. An analysis of the coal is given at the end of this section.

No. 9 bore (north of No. 8), 185 ft. deep: At 100 ft. to 110 ft. broken coal and brown shale; at 140 ft. to 185 ft. conglomerate.

No. 10 bore (north-east of No. 8), 147 ft. deep: At 103 ft., 20 ft. of clean coal (main seam); at 142 ft. to 147 ft., conglomerate.

No. 11 bore (north-east of No. 10), 156 ft. deep: At 6 ft., 2 ft. coal (perhaps the upper seam); at 23 ft., 1 ft. dirty coal. Layers of conglomerate at 44 ft., 52 ft., and 64 ft., and from 70 ft. to bottom of hole with the exception of brown shale at 88 ft. to 92 ft.

No. 12 bore (between Nos. 10 and 11), 136 ft. deep: At 46 ft., 1½ ft. coal (? upper seam); at 79 ft. 6 in., 4½ ft. coal; and at 86 ft., 3 ft. coal (these two seams may together represent the main seam); at 101 ft. 6 in., 6 in. coal; at 113 ft. to 136 ft., conglomerate.

No. 13 bore (north-east of No. 11), 111 ft. deep: At 8 ft. 6 in., 1 ft. 6 in. brown shale with bands of coal; at 19 ft., 5 ft. coal (probably lower seam); from 78 ft. to bottom, conglomerate.

No. 14 bore (north-east of No. 13, on Chasm Creek side of watershed), 124 ft. deep: At 74 ft., 1 ft. coal; at 75 ft., 1 ft. 6 in. brown shale with coal bands; at 76 ft. 6 in., 4 ft. 6 in. coal; at 119 ft. to bottom, gneiss. The horizon from 74 ft. to 82 ft. may be considered to represent the main or lower seam.

No. 15 bore (south-west of No. 1), 110 ft. deep: At 15 ft., 1 ft. coal (upper 6 in. dirty); at 22 ft., 2 ft. dirty coal; at 53 ft., 3 ft. coal; at 90 ft. to bottom, granite.

No. 16 bore (between Nos. 6 and 9), 189 ft. deep: No coal. Coarse conglomerate from 164 ft. to the bottom.

Near the head of Frank Brook, a tributary of Reed Brook, is a thin outcrop of coal which is associated with sandstone and grit and probably belongs to the horizon of the lower seam. Somewhat more than half a mile to the west of north loose coal was seen at 840 ft. above sea-level in a branch of Patten Creek, a stream draining part of the western slope of Radcliffe Ridge. Thin outcrops of coal have been reported from this locality, and doubtless occur, though none was actually seen by the Geological Survey party.

About 30 chains north-east of No. 2 bore, 4 ft. of fairly good but friable coal is exposed in a short prospecting-drift at a height of 560 ft. above sea-level. The coal, which lies nearly flat, has a dark shaly roof and a fireclay floor. Nine chains south of trig. station AQ, 18 in. of good coal, underlain by 6 in. of dirty shaly coal, outcrops in a small gully at a height of 680 ft. The roof is sandstone, and the floor dark shaly sandstone, striking 310° and dipping at 8° to the south-west. A thick but friable coal-seam was exposed in 1911 during the construction of the Yellow Silver-pine Exploration Company's tram-line at a point 20 chains south-south-east of the last-mentioned outcrop. Its horizon is probably the same as that of the Hut seam and of the coal which outcrops in Chasm Creek 36 chains to the eastward.

The upper seam in the Charming Creek valley is everywhere too small to be worked under New Zealand conditions. The lower seam, however, has a maximum thickness of 21 ft. 9 in. (at bore No. 8), and bores Nos. 1, 5, and 10 each show 20 ft. of coal. The seam, however, rapidly thins in all directions outside the triangle formed by bores 1, 5, and 10, so that the proved area of workable coal does not exceed 200 acres. East, south, and west of this area the coal ultimately completely disappears. North-eastward, as shown by bores 12, 11, 13, and 14, coal continues into Chasm Creek valley, but is only from 2 ft. to 5 ft. thick, and, according to the driller's reports, is not of good quality.

Though an inclined drift or dip is quite practicable, the Charming Creek field can be best worked from a shaft placed near No. 5 bore, and in either case the mine-water will have to be pumped from a depth of about 100 ft. Since the coal is nowhere deep, the actual opening out of a mine will not be a very costly undertaking, but as regards transport to the railway the case is far different. The most economical plan appears to be the construction of an endless-rope tramway to Seddonville passing through tunnels on either side of Chasm Creek, and crossing that stream by means of a bridge. An alternative is a railway up the Ngakawau River and Charming Creek, which would be exceedingly expensive to construct, but would save eleven miles of haulage on the main railway-line. Other plans may be suggested, but all would be costly, and under present conditions there is little probability of the outlay being repaid by the profit derived from the sale of the coal. Roughly, the proved workable coal may be estimated at 1,500,000 tons, and the highly probable workable coal at an additional 900,000 tons. The extractable coal cannot be estimated on account of various unknown factors. Only in case of an assured working-profit exceeding 2s. 6d. per ton on all coal handled can the project of mining the Charming Creek area be considered commercially feasible.* So far as proved by the bores, most of the coal is hard and, to the eye, of good appearance, but more analyses are necessary in order to ascertain its exact quality, for the material from Nos. 1 and 8 bores of which analyses are quoted below was contaminated by shale, some of which came from stone bands in the coal-seam itself, and some, but probably not a great deal, from the sides of the bores above the coal.

These analyses are as follows:—

——	1.	2.	3.	4.	5.	6.	7.	8.
Fixed carbon ..	50·26	36·72	46·82	50·98	49·57	38·37	45·54	46·58
Volatile hydrocarbons ..	36·93	34·63	38·39	39·01	37·36	33·72	36·41	39·56
Water	2·28	2·09	1·93	2·03	2·29	2·16	2·14	2·07
Ash	10·53	26·56	12·86	7·98	10·78	25·75	15·91	11·79
Totals ..	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Total sulphur per cent.	4·64	3·37	4·35	4·04	2·75	3·59	3·97	4·68
Calories per gram ..	..	..	..	..	..	..	6,627	..
British thermal units per pound	..	..	..	..	..	..	11,929	..
Evaporative power per pound in pounds of water at 212° F.†	..	..	..	..	..	..	12·36	..
Specific gravity ..	..	..	..	..	..	..	1·323	1·339

(1.) First coal sample from No. 1 bore.

(2, 3, 4, 5, 6). Samples at 6 ft., 10 ft., 13 ft., 16 ft., and 20 ft. in coal, No. 1 bore. Fairly bright and hard coal. Contains pieces of carbonaceous shale. That from 20 ft. is rusty.

(7.) Analysis of samples 1–6 mixed.

(8.) Coal from No. 8 bore. Hard coal, varying from bright to dull in lustre.

According to separate tests, the bright coal from No. 8 bore contains 4·20 per cent. of ash, and the intermixed carbonaceous shale 46·70 per cent.

(3.) *Blackburn Area.*—Between Upper Chasm Creek and the Upper Ngakawau River is a considerable area covered by Kaiata mudstone, beneath which there may or may not be a productive coal horizon. So far as the occurrence of inliers of gneiss or granite without encircling outcrops of coal enables deductions to be made, so far must the inference be drawn that coal is not present except possibly towards the Glasgow fault. In the Blackburn Valley, however, thick outcrops of coal appear, and the probability of a workable field may be granted. The district is most easily reached from the Westport-Stockton lease, but access is also given by the Mokihinui-Lyell foot-track, which passes through the eastern part of the possible coal-bearing area. A branch track (not shown on the maps) leads from the north side of St. George Stream to the junction of that stream and the Ngakawau River. The Yellow Silver-pine Exploration Company's tram-line affords yet another route to the neighbourhood.

A quarter of a mile above the mouth of St. George Stream the Blackburn Stream enters the Ngakawau at a point 760 ft. above sea-level. For half a mile or more

* The possibilities of the Charming Creek area are discussed in the Fifth Ann. Rep., N.Z.G.S., 1911, p. 9; and in Appendix B of Mines Report, C.–2, 1912, pp. 102–3. (See also map opposite p. 104.)

† Practical evaporative power may be taken as 60 per cent. of evaporative power as calculated from the calorimeter test.

above its mouth the Blackburn cuts through Kaiata mudstone, this being succeeded by gneiss and granite, which form the walls of a rugged gorge. Above the gorge mudstone with many calcareous concretions again appears for some distance. Gneiss, with bands and irregular masses of pegmatite and ordinary granite, next forms the stream-bed. In places a little conglomerate and grit may be seen resting on the gneissic rock. About two miles above the mouth of the stream the gneiss disappears, and a dark micaceous mudstone, in places shaly, becomes the prevailing rock. This at two miles and a half passes into or is underlain by sandstone and grit. In these rocks, which strike 204°, and dip 10° to the east-south-east, two small coal-seams, one 3 in. thick and the other 8 in. or 9 in. thick, are visible. Somewhat higher up the stream the following section is seen: Grit, succeeded in downward order by 10 in. to 12 in. dark shale, 9 in. coal, 2 in. to 3 in. shale, 7 in. coal, 5 in. carbonaceous shale, micaceous shale (see Fig. 7A). These rocks strike 236°, and dip at 12° to the south-east. A small outcrop of granite next appears, ended by a considerable fault, beyond which is mudstone. Five chains above the granite a small stream enters the Blackburn from the westward, and less than 2 chains up is a fault, in which some crushed coal seems to be involved. Beyond this clean hard coal outcrops for over 20 ft. in the stream-bed at a height of approximately 960 ft. above sea-level. The total thickness of coal cannot be estimated from the exposure, but exceeds 10 ft., and may be much more. The roof, which is decidedly irregular, consists of grit, passing into fine sand stone. This again passes into mudstone, shaly in its lower layers, of which a thick ness of 60 ft. or 70 ft. is visible in the cliff formed by a waterfall at this point. The strata have a very slight dip to the south-westward. They are diagramatically illustrated by Fig. 7B.

For some distance up-stream the principal rock is a marine shaly mudstone or sandstone, striking about 210°, and dipping at 10° to 25° to the east-south-east. Search to the westward should therefore reveal outcropping coal. About 50 chains above the coal-outcrop just mentioned a large open flat—the Blackburn pakihi—appears on the western side of the stream. Opposite a small isolated hill* of Kaiata mudstone, which occupies a bend of the stream, the following section is seen on the left bank, at a height of 1,130 ft. or 1,140 ft.: Shaly sandstone, followed downwards by 18 in. grit, 6 in. coal, 8 in. dark grit, 3 to 4 in. coal and shale, dark grit. These beds dip gently to the southward. Denniston's section No. 175 (page 169 of report) probably refers to this locality.

The seam observed at 960 ft. above sea-level may be expected to outcrop not far to the westward,† but up-stream nothing of interest is seen until, at a spot nearly a mile and a quarter to the south-south-westward, thick and clean coal appears in the bed of a small rill draining into the Blackburn. From this point coal of good quality and thickness may be traced southward to the low ridge dividing the head of the Blackburn from the Mackley watershed. The most striking outcrop is about 1,300 ft. above sea-level, and forms a ring round a flat-topped hillock three-quarters of a mile west of trig. station J; 25 ft. of clean hard coal is here clearly visible, and there is a further thickness not well seen owing to a talus accumulation, but on the supposition that there are no shale-bands the seam must be over 40 ft. thick. The roof is shale, capped by sandstone, striking nearly east and west, and dipping 10° or less to the north. An analysis of the coal is given on page 139. With the observations here given may be compared Denniston's section No. 171 (p. 168 of his report), which refers to the same locality.

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* This hill is probably that mentioned as "Island Hill" by R. B. Denniston. See G.S. Rep. No. 9, 1877, p. 169, and "Section through Orikaka (*sic*) Valley N.S.," opposite p. 112.

† Cox and Denniston mention a 10 ft. outcrop "north from Island Hill." See *op. cit*, pp. 117, 169 (Denniston's section No. 174).

Seven chains north of the coal hill, hard clean coal, evidently belonging to the seam there exposed, outcrops for 50 yards in the bed of a rill flowing through a bushed gully. This is probably Denniston's section No. 179. At 12 chains to the north-north-east several feet of coal is exposed in the bed of the main branch of the Blackburn. Three chains down-stream the following section is visible on the north bank: 10 ft. sandstone, underlain by 6 in. shale, and 2½ ft. of somewhat poor coal, with a shaly floor, striking 340°, and dipping 10° to east-north-east. The outcrops just mentioned probably, but not certainly, belong to a seam at a lower horizon than the large seam shown by the pakihi outcrops. A quarter of a mile east-north-east of the coal hillock, close to an old peg of W. M. Cooper's marked "1," 8 to 10 ft. (perhaps more) of very clean coal outcrops at 1,340 ft. above sea-level. The floor is dark sandstone; the roof consists of 6 ft. sandstone, followed by shale. A small flat-topped hill 15 to 20 chains to the north-north-east (station H 36 of W. M. Cooper) shows on its western side 6 ft. of coal, capped by sandstone, but the floor is not seen.

Twenty-nine chains west of trig. station J, 8½ ft. of hard coal (roof eroded), resting on shale, outcrops in a small gully. Lower down the same gully, and also towards its head, are various other coal-outcrops, but owing to the imperfection of the exposures the true thickness of the seam is nowhere apparent. In the absence of definite evidence it may be assumed that the coal exposed in this locality belongs to the large seam of the coal hill or island, nearly half a mile to the west-north-west. Since, however, the coal is near the basal ancient rocks of pre-Tertiary age, it may belong to a lower seam.

Denniston's sections Nos. 170 to 180 (pp. 169–70 of report) refer to outcrops in the Blackburn area, but only a few of the localities can now be certainly ascertained.

From the head of Blackburn pakihi to the thick coal-outcrop near Blackburn Stream at 960 ft. above sea-level is a distance of approximately three miles, throughout which a coal-bearing horizon is exposed or is near the actual surface. Much prospecting, however, is necessary before the presence or absence of workable coal in the two and a quarter miles between the known outcrops can be ascertained. In places surface trenching will reveal coal, but elsewhere shallow bores somewhat to the east of the probable line of outcrop will in general give more satisfactory results. In order to prove the coal to the dip—that is, to the eastward—bores of some depth will be necessary. Although, as may be seen upon inspection of the maps, the possible coal-bearing area is large, extending eastward to the foot of Mount Berners (trig. station AD), and north-eastward to the Glasgow fault, experience in other portions of the Westport district shows that workable coal as a rule is not continuous for great distances. In this connection the Charming Creek coal-basin may be mentioned as perhaps an extreme instance of lenticularity in a coal-seam, but one which serves to show the need of proper exploration before estimates of quantity can be made. Actually the proved coal of the Blackburn district is comparatively small in quantity, and cannot be considered to exceed 3,000,000 tons, as estimated in a later section of this chapter.

(4.) *Mackley or Orikaka Valley.*—On or near the low ridge that trends westward from trig. station J and separates the head of Blackburn Stream from the Mackley Valley are various coal-outcrops, most of which are thin, and none of importance. Southward from this ridge stretches, between Tiger Creek and the Mackley, country of moderate relief, partly covered by low forest and scrub, partly almost bare of vegetation. This area was surveyed by W. M. Cooper, for a number of his pegs have been found, but only a small portion of it was included in the published maps of his surveys. From it the coal-measures have been almost entirely stripped by denudation, but a few patches, easily distinguished from a distance by the absence of forest and the nearly flat or gently sloping surface in accordance with the bedding, still remain. The largest and most southern of these patches, known to the Geological Survey party as Tiger pakihi, has a length of 64 chains, with a maximum width of 47 chains. The north-eastern part contains a few acres of coal-bearing ground, but the remainder shows only barren grit, overlying gneissic and allied rocks. One of the more northerly outcrops of the coal-measures shows the following section at a point 1,310 ft. above sea-level: 10 ft. grit, underlain by 7 ft. sandstone with a little shale; 3½ ft. good coal; 2 ft. shale; and 20 ft. sandstone passing into grit. These beds strike on the average 276°, and have a southerly dip of 8°. Fourteen chains to the southward, also at a height of 1,310 ft., 11 ft. coal, which has been prospected by a short drift, is visible. The immediate floor is shale, and the roof consists of 15 ft. of sandstone. The analysis of a sample of the coal appears on page 139 (No. 11).

Less than a mile south of Tiger pakihi, but separated from it by the deep gorge of the Mackley River, is a long, somewhat narrow strip of pakihi at much the same elevation, which is traversed by the so-called Buller County Council prospecting-track. The lower grits and sandstones of the coal-measures form its surface, but only a very small portion is coal-bearing. A section exposed at a height of 1,290 ft. in a little rill-bed near the centre of the pakihi is as follows: 4 ft. of coal (roof not visible) underlain by 4 in. shale; 6 in. coal; 6 ft. shale and sandstone with two little coal-seams. These beds lie almost horizontal. South-eastward, in several of the little streams draining into Plateau Creek, more or less loose coal may be seen, but it is quite evident that this locality is denuded of all workable coal.

The grits of the pakihi mentioned above appear to extend into a large forested district to the east and north-east, which is shown by the map as occupied by rocks of the Eocene coal-measures. The total area so covered, including the pakihi and a portion east of trig. J, which is almost cut off by the gneissic rocks of the Mackley Gorge and of Mount Berners, is roughly 11½ square miles. In all this country only two outcrops of coal have been found.* One of these consists of a small impure seam between 6 in. and 12 in. thick, which is visible at the foot of a sandstone cliff close to the Mackley River, 48 chains south-east of trig. station J, and 900 ft. above sea-level. The other outcrop is on the left (here the western) bank of the Mackley, about a quarter of a mile above Mossy Creek junction, and at a height of approximately 1,130 ft. above sea-level. The coal is 3½ ft. thick, hard, and of moderately good quality (see analysis on page 139). The roof is dark sandstone, and the floor shale, underlain by a thin stratum of conglomerate, which rests on gneissic rocks. The coal strikes 295°, and dips a little over 14° to the south-south-west, but in this direction is cut off by a fault within a few feet.

The only other indication of coal observed during the geological survey of the Upper Mackley Valley consisted of coaly streaks in sandstone near the Mokihinui–Lyell track east of Mount Berners (trig. station AD). In addition Mr. J. M. Cadigan, who was attached to the survey party as chainman during a period subsequent to the survey of the Mackley country, reported that during a prospecting expedition some years previously he had seen 8 ft. of coal a short distance south of the Mackley near the point where the Glasgow fault crosses. To the writers it seems probable that this coal is not of Eocene age, but is brown or pitch coal belonging to the Oamaru Series. In that case the strip of Miocene rocks shown on the map as ending half a mile south of the Orikaka ought to be extended somewhat to the northward. An alternative hypothesis is that the outcrop occurs in a fault-involved strip of the lower Eocene coal-beds. Though, unfortunately, no opportunity of investigating the occurrence presented itself, the matter is not one of pressing economic importance.

* In addition to that mentioned above.

It seems likely that the Blackburn seam lives into a portion of the area between trig. J and the foot of Mount Berners, whilst the 3½ ft. coal seen in the Mackley above Mossy Creek junction must have some extension to the southward into an unexplored area. For these reasons prospecting along the boundary-line between the Eocene coal-measures and the gneissic rocks would probably reveal coal-outcrops.

On the eastern slope of Mount William Range are several patches of Eocene coal-measures, the remains of the once continuous sheet that extended over the whole of the Mackley Valley. Owing to denudation, practically no coal now remains, except near the crest of the range, a locality described on a later page.

Southward the main block of Eocene coal-measures in part terminates against granite and gneiss, in part passes underneath Miocene rocks. It is believed, however, that owing to pre-Miocene denudation, or perhaps because Eocene rocks were never deposited over any large area in this direction, the possibility of bituminous coal-seams beneath the Miocene strata is small. The Miocene coal of the lower Mackley Valley and adjoining area, so far as contained in the Orikaka Survey District, is described towards the end of this chapter.

For many years the Mackley Valley was reputed to contain a large field of bituminous coal, and the discovery of the slender foundation on which this reputation rested came as a shock to the writers. To some extent, the erroneous, or at least confusing, announcements made by Cox* and Denniston† that the Blackburn coal occurred in the Orikaka (or Mackley) Valley may have formed the basis of these mistaken reports. The district undoubtedly contained a vast amount of coal in a bygone age, but through denudation the greater part has almost entirely disappeared. In the portion of the valley still containing the undenuded coal-horizon the indications of workable coal are scanty, but careful prospecting may perhaps lead to the discovery of a workable area. Such prospecting, however, should be preceded by some improvement in the means of access, and at the present time is hardly worth while, for under existing conditions the coal, even if found in larger quantity than seems probable, cannot be profitably worked, owing to the great difficulty and expense of constructing the necessary transport roads.

(5.) *Valleys of Granity, Mine, and Mangatini Creeks, or Millerton–Darlington–Mangatini Area.*—Granity, Mine, and Mangatini creeks drain an important coal-bearing area now being mined by the Westport and Westport-Stockton companies. Most of the coal is at heights ranging from 1,000 ft. to 3,000 ft. or more, but a few outcrops occur at lower levels. One of these, on the south bank of the Ngakawau River just below Mine Creek junction, is practically at sea-level, and shows, or rather did show, friable crushed coal to the thickness of 16 ft. to 18 ft. This is underlain, so far as can be seen, by a thin layer of shale, succeeded by coarse sandstone and grit that strike 200°, dip at 50° to the south-westward, and rest on granite. The roof of the coal is a somewhat fine grit, followed by a considerable thickness of yellow sandstone, containing two or three shaly layers, with a strike of 180° and a westerly dip of 40°. (See fig. 8 and Denniston's No. 1 section, p. 141 of report.) Mudstone, containing sandstone, grit, and pebble bands is exposed for some distance down the river-bank, with dip varying from 30° to 90°. The section is highly faulted, and is in fact involved in the Lower Buller or Kongahu fault-zone. Fig. 8 is a diagrammatic representation of the part near Mine Creek. The coal was worked in a small way many years ago by the Albion Coal Company, and later by the Westport-Ngakawau or Westport-Wallsend Coal Company. It lies between two faults, with parallel strikes,

* "Report on Survey of Buller Coalfield." Rep. G.S., No. 9, 1877, pp. 116–17.
† *Op. cit.*, pp. 139, 168.

and is a small isolated block, a somewhat fortunate circumstance, since the extension of the fire now consuming it is thus limited. On top of Crane Cliff, to the eastward of Mine Creek, thick but extremely friable coal outcrops, and there are several similar outcrops of sooty coal on the north side of the Ngakawau near and below the old sawmill tramway. These are not shown on the maps. Denniston's outcrops Nos. 2 and 3 are on the east side of lower Mine Creek; No. 6 is well up Steep Creek; No. 5 on top of Crane's Cliff; No. 3½ in lower Brown Creek; and Nos. 7 and 8 between the heads of South and Brown creeks (see pages 141–42 of his report).

From Crane Cliff far to the eastward is an extensive area on both sides of the Ngakawau River which is devoid of workable coal. In this barren district are included Rome Creek valley, the lower Mangatini Valley, Repo Creek valley, the pakihi north of the deep Ngakawau Gorge near trig. station AN, lower St. Patrick and St. Andrew valleys, &c. Again, southward towards Millerton there is little evidence of workable coal. East of Millerton is an area which has been bored with poor results. In Mine Creek, about two to two miles and a half from its mouth, Denniston reports 2 ft. to 3 ft. of coal (sections 4 and 9, pages 141 and 142 of report). On a line drawn eastward from this point, coal approaching workable thickness begins to live, and is seen in Sandy Creek south of Darlington (Denniston's section No. 13), and again in a gorgy part of Mangatini Creek a mile to the south-east (Denniston's section No. 14) at 1,190 ft. above sea-level. In the latter locality the outcrop may be seen for a quarter of a mile along the western wall of the gorge, so that a very fine and interesting section is exposed. The coal-seam is lensoid, thickening from a thin coaly band enclosed in shale to 4 ft., and then thinning to 16 in. or less. Lenses of shale, sandstone, and grit are enclosed in the seam (see Fig. 9A). The roof consists of a little shale and sandstone overlain by a great thickness of grit, and the floor of several feet of dark shale underlain by grit. These beds strike 266° and dip at 12° to the north. Somewhat to the southward 15 in. of coal thinning to 12 in. is visible on the eastern side of the gorge and in AJ Creek.

Less than a quarter of a mile up-stream 7 ft. to 8 ft. of hard coal appears on the eastern side of the gorge at 1,300 ft. above sea-level. The strike is 266° and the dip is at first 15° to the north, but southward flattens. A grit lens is visible in the seam (see Fig. 9C, which also illustrates a curious variation in the immediate roof from grit to shale, caused by current-bedding). Just to the south of the point where the outcrop, owing to the flattening of its dip and the rise of the stream-bed, disappears below water-level, is the Millerton fault, which has here a strong upthrow to the south. The upthrown coal is probably not very thick, for outcrops have not been observed for some distance southward.

At a point almost a mile to the west, on the south side of the Millerton fault, 2½ ft. of coal is visible on the east side of Mine Creek near the Westport-Stockton electric tramway. On the other side of Mine Creek the same seam may also be observed, gradually increasing in thickness to 6 ft., and, as Mine Creek township is approached, to 10 ft., 15 ft., and more (see Denniston's sections Nos. 15, 16, and 17). Thick coal extends from Mine Creek north-west towards Millerton, and has been extensively worked by the Westport Coal Company. Southward from Mine Creek to Mangatini township the coal is uniformly thick, and on the south side of Mangatini Creek reaches the great thickness of 53 ft. or 54 ft. The numerous magnificent outcrops of clean almost ashless hard coal in this locality cannot fail to arouse enthusiasm in the spectator. Fig. 10 illustrates one of the outcrops visible near Mangatini township. So far as can be determined by outcrops, thick coal, belonging to what may now be called the Mangatini seam, extends from here to the summit of Mount Augustus (3,311 ft.) The cover of the coal consists of from 50 ft. to 100 ft. of grit and sandstone.

Good outcrops not far above basal granite appear on the steep seaward slope near Mount Augustus, and northward, towards Millerton, many fine outcrops may be seen in the upper watershed of Granity Creek and in the area immediately to the westward. At one point 30 ft., and at another probably close on 50 ft., of clean coal, unmarred by shale bands, may be seen. In several places there are two seams, separated by a few feet of shale and sandstone, but these may be regarded as splits from one main seam. On the whole the coal-outcrops make a splendid show, though in and near Granity Creek, at a locality about two miles south of Millerton, the coal is somewhat thin, and in one place seems to be wholly replaced by dark carbonaceous shale, which there is reason for believing extends as a belt of some width to the south-south-east.

In the gorge of Granity Creek, half a mile to a mile south of Millerton, are some very good outcrops. Again, less than half a mile south-east of that township, about 20 ft. of coal is visible in Miller Creek (a branch of Granity) near the Westport Company's air-compressor plant. Other outcrops in or near Miller Creek watershed are shown by W. M. Cooper's maps (see also Denniston's sections 19, 20, and 21).

If attention is again turned to the neighbourhood of Mangatini township, where the coal of the area under description attains its maximum thickness, it will be seen that the maps show various outcrops to the south-east in Ford Creek valley, and eastward for some distance down Mangatini Creek valley, or rather gorge. East of the Westport Company's boundary the Mangatini seam, here from 8 ft. to 16 ft. thick, has been worked by the Westport-Stockton Company from its B, C, and D tunnels. In these workings much of the coal, though otherwise of good quality, is friable. Figs. 11A and 11B show two sections near D tunnel. Not far to the east of B tunnel, however, workable coal ceases to exist, owing to the thinning of the seam, and the same thing happens 20 chains or so below the bridge over Mangatini Creek between B and C tunnels. Possibly thin coal lives down the stream on the west side as far as the Millerton fault, beyond which, it will be remembered, a 7 ft. to 8 ft. seam outcrops in the Mangatini Creek gorge. The area east of the Mangatini appears to be denuded, but may in reality have been originally devoid of coal.

East of C and D tunnels the coal thins considerably, and, moreover, reaches the surface, so that the seam can be traced no further in this direction. It lives, however, beyond the southern boundary of the Mangatini watershed, and presently, in describing the next area, some highly interesting data concerning it will be given.

Various outcrops of the Mangatini seam which have not been specifically mentioned are indicated on the maps published with this bulletin, and others, shown on Cooper's maps, are described by Denniston.

In general the floor of the Mangatini seam consists of a thin layer of shale, underlain by coarse sandstone and grit, the latter rock in places passing into conglomerate. As a rule, the basal granite or gneiss is not far below the coal, but east of the Westport-Stockton Company's C and D tunnels the interval is considerable. Coincidentally the coal thins. The bed immediately overlying the coal is in places shale, but generally consists of hard sandstone or fine grit, and therefore forms a safe roof for the miner. These latter rocks (sandstone and grit) with minor bands of shale, extend to the surface, the soft Kaiata mudstone, which once overlay them, having been entirely removed by denudation. The cover of the coal is therefore usually from 50 ft. to 100 ft. thick, and the surface slopes approximately correspond to the bedding, thus indicating the attitude and depth of the underlying coal.

The Millerton-Mangatini area of workable coal is traversed by only one fault of any magnitude, the Mangatini.* The Millerton fault, somewhat curiously, roughly indicates for some distance the line dividing this area from the almost barren district

* For descriptions of this and the Millerton fault see Chap. IV.

that extends northward as far as Charming Creek, and to the eastward has a still greater extension. In striking contrast the country south of the Millerton fault abounds, as has been shown, in thick coal of good quality. Inspection of the outcrops and the mine-workings conveys the impression that here is an immense supply of fuel, though one may also observe that the coal has been denuded from stream-valleys, that in one or two localities it is thin and inclined to pass into shale, and that in various places, though of high calorific value, it has the defect of friability. The great thickness of the coal over much of the area very seriously decreases the proportion that can be won, for no method of total extraction is practicable. Again, a considerable block north of Mine Creek township has been sealed off owing to fire, and thus some coal has been destroyed, whilst a considerable amount is at least temporarily lost.

(6.) *Fly Creek, Plover Creek, and Upper St. Patrick or "South Branch" Area.*—The coal-bearing area drained by the upper part of the St. Patrick Stream (commonly called the "South Branch of the Ngakawau") and its branches, T 35, T 31, Fly, and Plover creeks, lies immediately south of the Mangatini district, with Mount Augustus at its north-west corner and trig. station AH near its north-east corner. In shape it is an irregular trapezium, measuring from east to west about two miles and a half, south of Mount Augustus one mile and a half, and south of AH somewhat over three miles. On the east it is bounded by the Mount William fault and the gneissic slopes of Mount Stockton, on the west by the water-parting trending north from Mount Frederick, and on the south by the Upper Waimangaroa area. From the western water-parting, with a maximum height of 3,380 ft. or 3,400 ft. the area slopes with rough uniformity to the eastward, the lowest ground in this direction being somewhat over 1,800 ft. above sea-level. The surface is everywhere formed by hard grit or sandstone, in which the consequent streams have cut gorges of varying depth.

A highly important group of coal-outcrops occurs in the eastern part of the St. Patrick area, a little to the north of T 31 Creek. The steep sides of a low flat-topped hillock in this locality, at an approximate height of 1,900 ft. above sea-level, show a 25 ft. outcrop, oval in plan, of somewhat tender but clean coal. This may be regarded as belonging to the Matipo seam, so named from an outcrop in Fly Creek, which will presently be described. The coal floor consists of a little shale, below which is a few feet of coarse sandstone and grit, resting on the basal gneissic rock. The roof is 6 in. of fine grit, succeeded by 6 ft. of coarse grit, above which is 6 ft. of somewhat finer-grained grit. These beds strike 278°, and dip at 6° to the north.

A few chains to the north-west, at the base of a low cliff broken by several gullies, the same thick seam shows two strong outcrops, horse-shoe-shaped in plan, owing to their curving around the spurs. The roof is everywhere coarse grit, from 2 ft. to 5 ft. thick, followed by somewhat finer-grained rocks. On the curving sides of the horse-shoes the coal splits in a most interesting way. A shale parting that appears in the coal 2½ ft. from the roof rapidly thickens to the west, and as it does so in part passes into sandstone, which again passes into current-bedded grit. In the little gully due west of the coal island the distance between the two splits increases very rapidly, the upper seam rising to the westward, whilst the roof of the lower seam actually shows a downward tendency (see Fig. 12B). Four chains to the south-west, across the gully, the upper seam has a strike of 158°, and a dip of 20° to the north of east. The coal is here over 3 ft. thick, with a roof consisting of 10 in. coarse grit, 5 in. sandstone, and 10 ft. grit with sandstone bands. The floor consists of shale (thickness not noted) underlain by sandstone and grit, of which a considerable thickness is seen.

In the next little gully 3 or 4 chains to the north the following section is seen: 8 ft. grit, underlain by 6 in. sandstone passing into grit right and left; 2 ft. coarse grit;

2½ ft. or more of coal; 1 ft. sandstone, thickening to the south-westward; 12 ft. coal (floor not seen). About 15 yards to the south-west the roof of the main seam makes a sudden dip (perhaps due to a "washout"), but the bedding of the sandstone above the coal remains parallel to its former direction (see Fig. 12A).

On the south side of a third gully, a few chains to the northward, a remarkable section showing the split is visible. To the east 12 ft. of clean, hard coal with grit roof (floor not seen) is exposed for a distance of 2 chains or more. A rusty band in the seam 2½ ft. from the roof represents the first trace of a split. For a distance of 14 yards to the westward the coal is obscured by débris, and then the following section is seen: 10 ft. grit, underlain by nearly 3 ft. of coal, 5 ft. shale and sandstone thickening westward, 7 ft. coal with floor not visible (see Fig. 12D). Less than a chain farther to the west the section becomes: 6 ft. grit; 3 ft. coal; 6 in. shale; 6 ft. shaly sandstone; 3 ft. sandstone, thickening very rapidly to the west, and passing into coarse current-bedded sandstone; 6 ft. coal with floor not seen (see Fig. 12C).

The 3 ft. upper split, owing to denudation, cannot be traced far to the westward, but to the south-west occasional outcrops representing remnants of the seam are fairly common. The seam thickens somewhat in this direction, and near the Westport-Stockton No. 1 bore shows 5 ft. of fair coal. From this point it may be traced by almost continuous outcrops far up Fly Creek. The thickness increases to 6 ft. or more three-quarters of a mile west of the bore, whilst at a mile, beyond a considerable fault, thick coal undoubtedly in the same horizon, and known to belong to the Mangatini seam, is found. Thus it becomes certain that this great seam originates as a split from the upper part of the thick seam outcropping near T 35 Creek. The following sections observed between T 31 Creek and the upper part of Fly Creek illustrate the changes in the nature of the seam and the enclosing strata :—

1.	2.	3.	4.
..	—sandstone and grit.	..	..
6 ft. grit.	6 ft. grit.	6 ft. grit.	6 ft. grit.
6 ft. sandstone.	4½ ft. sandstone.	2 ft. sandstone.	
2½ ft. coal			3 in. dirty coal.
11 in. shale.	5 ft. coal.	5 ft. coal.	
2 ft. coal.			6 ft. good coal.
6 in. shale.	2 ft. shale.	— shale.	9 ft. shale.
— sandstone.	Small blank.	— grit.	Blank.
..	— grit.	..	70 ft. or more of grit.
..	..	..	Conglomerate.

(1 and 2.) South-east from Westport-Stockton No. 5 bore.

(3.) Near Westport-Stockton No. 1 bore.

(4.) Sixty chains west of No. 1 bore, near upper gorge of Fly Creek. Coal 2,450 ft. above sea-level.

The following is a somewhat composite section obtained by comparison of the outcrops close to Fly Creek southward from the Westport-Stockton D tunnel workings: Alternating grit and sandstone, varying in thickness, according to erosion of surface; 10 ft. grit; 2½ ft. coal increasing westward to 3 ft., decreasing eastward to 2 ft. or less; 5 ft. shaly sandstone, increasing westward to 6 ft., decreasing eastward to 4 ft.; 15 ft. coal, clean and hard; 12 ft. shale; 30 ft. coarse grit. Height of coal above sea-level, 2,620 ft.; dip at moderate angles to east or east-north-east. Fig. 13 illustrates this section.

South from upper Fly Creek and Mount Augustus the Mangatini seam shows many outcrops, but, owing to denudation, the total area carrying coal is not so large as could be wished. Moreover, in places shale replaces the coal to a considerable extent, this being apparent in a nearly denuded area about three-quarters of a mile south-east of Mount Augustus. Especially fine outcrops of coal (6 ft. to 25 ft. thick, according to Denniston) appear in the headwaters of Plover Creek whence, however, the distance to the steep slope west of the watershed is small, and therefore the workable belt of coal is narrow. Eastward of this belt the Mangatini seam has been almost wholly removed by denudation. The only outcrop observed that may belong to it is not quite three-quarters of a mile east-south-east of trig. station L 41, and half a mile south of Plover Creek. Here, on the north side of a small branch of St. Patrick Stream, 3 ft. of coal with a roof of yellow grit and a shale floor outcrops. It would be interesting to identify this outcrop with the Mangatini seam, for this would indicate a thinning of the seam, and a probable ultimate junction with the lower or Matipo seam, corresponding in both respects with the observations made farther to the north.

The reader's attention may now be turned to the lower or Matipo seam, from which the Mangatini has split. This may be traced northward by its outcrops to a point half a mile south-east of trig. AH. Here, in a small hill near T35 Creek, the following section may be seen at a height of 1,940 ft. to 2,000 ft.: 7 ft. grit and coarse sandstone; 20 ft. fine shaly sandstone; 30 ft. grit and sandstone in alternating layers, the former predominating; 7 ft. good coal with a shale floor. About 30 yards to the eastward the seam has thickened to over 12 ft., but contains a shale band. The floor is shale for several feet, below which there seems to be more coal. The strata of the hill strike 274°, and dip at 10° to the north. Beyond this point the lower seam cannot be traced, and probably to the northward it thins. Without much doubt it once extended eastward over the present slopes of Mount Stockton, but from this quarter it has been entirely removed by denudation.

The Matipo seam may be traced southward from T31 Creek with more or less certainty for several miles. Not quite half a mile south-south-west of the coal hillock showing 25 ft. of coal an outcrop at least 16 ft. thick (2,020 ft. above sea-level) is exposed on a cliff face a few chains west of St. Patrick Stream. The roof consists of many feet of fine to moderately coarse grit. The floor is not seen owing to the débris piled at the foot of the cliff, but not more than 40 ft. below is the basal gneiss on which the coal-measures of this locality rest. The coal strikes 329°, and dips at 12° to the north. This dip, however, like many others recorded on the coalfield, is but local. Coal ought to outcrop in the gorge of St. Patrick Creek, a few chains above Fly Creek junction, but owing to the gorge being partly filled with huge blocks of grit and sandstone no outcrop is visible. The abundance of coal pebbles, many of them angular, in the stream-bed below this point proves that a seam, probably thick, does exist in the situation indicated. Coal ought also to appear near the junction of Fly and Plover creeks, but was not seen, though 25 ft. of coal (thickness probably exaggerated), known as Broome's outcrop, is reported to be visible on the south side of Plover Creek just above its junction with Fly Creek. A fault here present probably prevents coal from outcropping just where it might be expected, but 8 chains up Fly Creek coal, known as the Matipo outcrop, does appear at water-level on the north side of the stream. This shows between 9 ft. and 10 ft. of good hard coal, besides whatever may be below stream-level. The roof consists of grit, extending to the top of the cliffs bounding the gorge. The strike is irregular and the dip small. If the effect of faults be neglected, the average dip of the coal from the Matipo outcrop (2,070 ft. above sea-level) to the 16 ft. outcrop a quarter of a mile to the north-east, is under 4°.

No outcrops of the Matipo seam are visible in Fly Creek to the westward of that just described, though in this direction the gorges and bed of the creek show a continuous section of the overlying grit amd sandstone for nearly two miles. At a point not quite a mile and a quarter from the Matipo outcrop a strong fault with upthrow to the west crosses the stream. In consequence the basal conglomerate of the coal-measures is exposed, but in vain was search made for evidence of the Matipo seam in the beds overlying the conglomerate. A little dark shale was observed inter-bedded with the conglomerate and some distance to the west a thin bed of coal occurs 30 ft. below the Mangatini seam, but it is not likely that this represents the Matipo seam, which, according to the available evidence, should be over 100 ft. below the Mangatini. The conclusion reached then is that the Matipo seam completely thins out to the westward in the Fly Creek watershed. This belief is quite in accordance with the experience gained in other parts of the field regarding the lenticularity of the coal-seams, and is signally confirmed by the results of drilling in the area east and south of the C and D tunnel workings of the Westport-Stockton Company. Of the thirteen bores marked on the maps, all but the two marked "Old bore" were drilled by the company just named. So far as is known to the writers, the two old bores, 172 ft. and 220 ft. deep, either found no coal or only a very thin seam; bores B, C, 2, and 3 were similarly unsuccessful; and the bore D, 254 ft. deep, close to D tunnel, having found no coal worth mention below the Mangatini seam, reached gneiss. On the other hand, bore A, south-east of B, passed through 3 ft. of coal; bore No. 7 (marked 6E on a map issued by the Westport-Stockton Company), approximately 33 or 34 chains south-south-east of A, at a depth of 101 ft., entered 18 ft. of coal; a bore (7E on the map just mentioned) 23 chains south-by-west from No. 7 (or 6E) proved 10 ft. to 10½ ft. of coal at a depth of 104 ft.; No. 1 bore, on the north bank of Fly Creek, 28 chains west of the Matipo outcrop, penetrated 7½ ft. coal at a depth of 137 ft., and bore No. 6 (1F on the Westport-Stockton Company's map) on the north bank of Plover Creek, 27 chains south of No 1, penetrated 7½ ft. to 8 ft. of coal at a depth of 107 ft. Concerning the bore marked No. 5, which was drilled close to T 31 Creek, about 31 chains east of No. 3 bore, nothing has been learned. A bore (4E) 26 chains north-north-west of No. 1, and 32 chains west-south-west of No. 7E, and therefore about 22 chains south of No. 5 bore, found 5 ft. of coal at a depth of 117 ft. Some of these bores give important data concerning the thickness of the beds separating the Matipo seam from its split the Mangatini seam. At No. 7 or 6E bore, approximately 25 chains west-north-west of a point where the split is observed to begin, this thickness is 101 ft., to which must be added a few feet more, the Mangatini seam being here denuded. At No. 7E bore, about 30 chains west of an observed splitting-point it may be estimated at 110 ft. At bore No. 4E the discrepancy is 125 ft. or 130 ft. and at bore No. 1, which is somewhat over three-quarters of a mile from the nearest observed point of splitting, the distance between the seams is approximately 145 ft. (from roof to roof).

East of St. Patrick Stream, at a mile to a mile and a half above the Fly Creek junction, outcrops of coal may be seen practically on the line of the Mount William fault and more or less involved in it. On the east bank of the stream, near the point where, coming from the west, it bends to a general north-by-east direction, 5 ft. of coal (2,280 ft. above sea-level) is exposed, with floor not seen. Appearances in a little rill close by indicate 8 ft. of coal (perhaps more). The roof consists of 1 ft. of shale, overlain by sandstone, of which 12 ft. is seen. The strike is 188° and the dip 8° or 10° to the west, this reversal of the direction of dip from that prevailing to the west being due to the drag of the Mount William fault, which is only a chain or two away. As observed by Denniston the section (No. 63, page 148 of report) in this locality is somewhat different.

A few chains south-west of the last-named outcrop coal (height 2,300 ft.) shows for some yards in the bed of St. Patrick Stream. Greywacke and granite are exposed a chain or two away and therefore the coal must be very near the base of the coal-measures. Eighteen chains to the south-south-west 3 ft. of coal with sandstone roof dipping east-south-east is visible at a point practically on the flat water-parting between St. Patrick Stream and Cypress Creek, the latter a tributary of the Waimangaroa. Hence coal of similar thickness continues southward. To the west the coal is completely removed by denudation, but eastward it lives for 10 or 11 chains to the Mount William fault, beyond which is the almost entirely coal-denuded area of the William Range.

The data obtained in the course of the geological survey show that over a very considerable area the Matipo seam is of good quality and thickness. This area has a probable length of nearly three miles from a point half a mile or less south of trig. station AH to the point where St. Patrick Stream assumes a north-by-east course. The seam thins to the westward, whilst to the east of the outcrops described there is hardly any workable coal, owing to denudation. Only by boring or other form of underground prospecting can the width of the workable strip be determined. It may perhaps be assumed as approximating half a mile. If the average thickness of the coal be taken as 7½ ft., then 10,800,000 tons of coal, of which half may be extractable, is present. Probably, however, under prevailing conditions not more than one-third of this can be won at a profit, and therefore the estimate of coal that can be obtained from the area must be reduced to 3,600,000 tons. For the table on page 184, the coal has been calculated on a slightly different basis, but the result is not materially different.

Cox and Denniston failed to distinguish the Matipo seam from its split the Mangatini seam, and, taking outcrops of the latter for the former, mapped as barren the greater part of the area (roughly 1,000 acres) now known to contain the Matipo seam. The writers are unable to say to whom full credit is due for the discovery of the coal-bearing nature of the supposed barren ground, but certainly Mr. G. H. Broome, formerly General Manager of the Westport-Stockton Company, must be mentioned in this connection.

(7.) *Upper Waimangaroa Area.*—The upper Waimangaroa area may be defined as bounded on the north by the water-parting between the Waimangaroa River and St. Patrick Stream, on the south-east by the Mount William fault, on the north-west by the water-parting overlooking the ocean, and on the west by a line drawn almost due south from the head of Britannia Creek to the Mount William fault. The surface has a general slope from the north-west to the south-east, the highest point (Mount Frederick) being 3,621 ft., and the lowest approximately 1,550 ft. above sea-level.

Near the headwaters of Whirlwind Creek, the most northern branch of the Waimangaroa, are some outcrops of the Mangatini seam at an elevation of 2,910 ft. Southward from this locality the possible coal-bearing belt is narrow, and, in fact, outcrops were not observed either by the writers or by Denniston and Cooper. Forming the summit of Mount Frederick, however, is an outlier of the coal-measures with an area of 153 acres, which is surrounded by greywacke and granite. Workable coal from 5 ft. or 6 ft. to possibly 20 ft. or more in thickness (Denniston, sections 68–73, pages 148–49 of report) outcrops close to the boundary, and extends over an area of 140 acres. The roof is usually shale from 2 ft. to 4 ft. thick, above which is sandstone and grit. The floor is shale or dark sandstone, not far below which comes greywacke or granite. In several places these rocks are almost in contact with the coal, and in consequence rotten and bleached through the extraction of iron and other constituents (see page 70). The coal of the Mount Frederick outlier apparently belongs to the Mangatini seam, but positive identification is not possible on the field-evidence alone.

Along the southern edge of the upper part of Deep Creek valley are a few outcrops of coal from 6 ft. to 9 ft. thick. To the southward again is an area containing numerous outcrops of clean coal from 5 ft. to 15 ft. or more in thickness. In places two, or even three, seams, separated by a few feet of shale and sandstone, are present; but the coal shows a tendency to pass into shale, and may be very patchy. West of the head of Billo Creek, a branch of Deep Creek, is the area formerly worked by the Koranui Company, where the coal as seen is from 6 ft. to 8 ft. thick. In the lower part of Deep Creek watershed the coal is now being actively extracted by the Westport Coal Company.

In various parts of the Deep Creek watershed the coal, as mentioned above, is to some extent replaced by shale, and since also the main seam gives off splits, exact identification of the most important coal-horizon becomes very difficult. For the same reasons any estimate of the quantity of coal will be unreliable, and only by boring and mining operations will correct data be obtained. The coal is very patchy, mainly owing to erosion; but the locality contains less barren ground than is shown by Cooper and Denniston's mapping.

The main coal-seam in Deep Creek watershed must presumably be correlated with the Mount Frederick coal, supposed to represent the Mangatini seam. The identification, however, is so very doubtful that it cannot well be regarded as more than a possibility. If this view be correct, it follows that the coal mined at Burnett's Face, Coalbrookdale, &c., belongs to the Mangatini seam. Probably the most reasonable view to adopt is that expressed on an earlier page—namely, that all the workable coal-seams are or were originally connected by splits, and that consequently there is only one main seam in the Westport district.

East of Deep Creek is an area (Kiwi Ridge) that shows only a few surface patches of coal, none of any importance, and is apparently barren. Boring, however, is necessary to determine whether or not deeper coal (corresponding to the Matipo seam) exists in this locality.

The reader's attention now has to be drawn to the belt of country lying immediately west of the Mount William fault, and traversed throughout by the Waimangaroa River. On a previous page is mentioned the 3 ft. seam outcropping in the watershed of Cypress Creek (Happy Valley), and regarded as representing the Matipo seam. In the bed of the Waimangaroa River a few chains above Cypress Creek junction coal 2½ ft. to 3 ft. thick, with a shaly roof, is exposed. The floor is also shale of some thickness, probably resting on grit, which is seen a short distance up-stream. The coal strikes 251°, and dips at 12° to the south-south-east. The same seam again outcrops 12 chains to the south-west, close to a nearly east-and-west fault shown on the maps.

At this point it is desirable to mention that correlation of any coal-outcrops to the southward of the fault mentioned above with the Matipo seam cannot be made. These outcrops may, in fact, equally well be correlated with the Mangatini seam, and this is hardly strange, for, as has been shown, the one seam is a split from the other. The tentative correlations here made are desirable rather as a means of giving a connected account of the coal occurrences than as an aid to actual mining, for, owing to the lenticularity of the workable seams, their frequent splits, and other factors, such as faulting, certainty regarding the presence or absence of coal in doubtful areas, as a rule, cannot be attained by identifying the coal-horizon, but only by actual exploration.

The first outcrop of coal seen south of Happy Valley is at an elevation of 2,180 ft. near a right-angled bend of the Waimangaroa. Here 6 ft. of coal (no floor seen), with a dip of 12° to the south-south-east, is exposed. Somewhat over a quarter of a mile to the south-east a fine section is visible at a height of 1,920 ft. on the east bank of the Waimangaroa just below Webb Creek junction. Denniston's section (No. 75, page 150 of his report) is given for comparison with that observed by one of the writers :—

N.Z.G.S., 1912.	Ft.	in.
Yellow sandstone	20	0
Coal	2	0
Sandstone	0	8
Coal	1	0
Yellow sandstone	8	0
Shale and coaly matter	0	5
Yellow sandstone, passing downward into shaly sandstone	7	0
Coal (floor not seen)	15	0
Blank, about	5	0
Shale and shaly sandstone.		
Coarse sandstone and grit (a considerable thickness).		
Strike about 244°. Dip 15° to south-south-east.		

Denniston, 1877 Report.	Ft.	in.
Soft yellow sandstone	12	0
Coal	2	0
Blaze	0	6
Coal	1	6
Soft yellow sandstone, with blaze partings	5	0
Band of blaze .. .. ..(?)	6	0*
Soft yellow sandstone, with shale ..	9	0
Coal	20	0
Blaze	2	0
Dip south to south-east. Resting upon hard grit.		

The coal is hard and perfectly free from shale-bands or other visible impurities. It is also observable on the west bank of the Waimangaroa, and may be traced some distance up Webb Creek by occasional outcrops, but in this direction almost certainly thins. The first outcrop seen shows 6 ft. or 7 ft. of good clean coal, with 6 ft. of shale roof overlain by sandstone. The floor, almost hidden by water, seems to be shale. The poor and unsatisfactory outcrops higher up the stream do not indicate thick coal.

Fifty chains to the south-west of Webb Creek is L 75 Creek, which shows some good outcrops of coal at 8 to 16 chains above its junction with the Waimangaroa. These afford the following composite section: Sandstone and grit, underlain by 6 ft. shale, 7½ ft. clean coal, and 2½ ft. of shale, resting on coarse sandstone.† The strike is 336°, and the dip 8° to 10° to the north-east. The strata, however, are interrupted hereabouts by two or three faults, which strike west of north. West of these, and on the south side of L 75 Creek, are several outcrops of coal at a height of about 2,250 ft. These strike slightly west of north, and dip at 10° to the east, and may or may not represent the seam seen farther to the east. Westward is an apparently denuded area, but Denniston shows coal in this direction as far as the base of the Kiwi fault-scarp, and in any case boring is probably desirable in order to prove one conclusion or the other.

Not far below the mouth of L 75 Creek very thick but friable coal outcrops on the west bank of the Waimangaroa. Something like 30 ft. (according to Denniston's section No. 77, 32 ft.) of coal may be seen. The roof appears to be shale, over which may be a considerable thickness of grit and sandstone, but a fault complicates the section, and is probably the cause of the coal being so thick. About 1½ chains up-stream 8 ft. or 9 ft. of coal lying under a shaly roof is exposed on the west bank, and is doubtless the same seam as that seen below.

* Probably this should be 6 in.

† Denniston gives a fuller section (No. 76, p. 150 of report), in which the thickness of coal seen is stated to be 12 ft.

About 18 chains south of the last-mentioned outcrops $3\frac{1}{2}$ ft. of fairly good coal, resting on conglomerate, is visible on the left bank of the Waimangaroa. The roof is shale and shaly sandstone passing into ordinary sandstone, of which 40 ft. is exposed. The last-named stratum contains a 5 in. coal-seam, and is overlain by marine mudstone (Kaiata beds). The strike of the larger coal-seam is 251°, and its dip 12° to the east of south; but to the westward the strike changes more to the north, and the dip veers to the eastward. Two small faults with strike of about 166° appear in the section. To the east nothing outcrops for 2 chains, and then Kaiata mudstone appears. According to Denniston a section (No. 78 of his report) that contains 30 ft. of coal occurs at or close to this locality. In 1912 search was made by the Geological Survey party, but no such outcrop was found.

Clean and workable but somewhat friable coal outcrops near the western bank of the Waimangaroa almost opposite Wilson Saddle. The exact thickness of the seam is not determinable without somewhat deep trenching.

Thirty chains or so to the south, and close to the point where the boundary-line between the Westport Coal Company's ground and what is known as "Cook's (or Westenra's) Lease" crosses the Waimangaroa, broken coal is visible on the western bank of the river. Immediately to the southward the following section appears on the east bank: 30 ft. yellow sandstone with a thin coal-seam and shaly layers, 30 ft. coarse gritty sandstone, 6 ft. soft yellow sandstone, 30 ft. coarse sandstone, 6 ft. varying sandstone, 11 ft. good coal (floor below water-level, and not seen). The section is Denniston's No. 80, which gives the thickness of coal as 20 ft.* Up-stream a band of shale appears near the middle of the visible coal. This thickens, and coincidentally the roof of the coal droops. There is here something more than a suggestion of what is commonly called by miners a "roll" (see page 180). For a chain or so the coal is invisible, and then an outcrop of hard coal with a shale roof makes its appearance. Fig. 14 is an attempt to illustrate the whole section. On the open ground, south of the 11 ft. coal-outcrop, a small upper seam from 1 ft. to 2 ft. thick, dipping at 12° to 20° to the south of east is seen in several places. It is apparently of no importance.

Immediately east of the point where the Aorere rocks that outcrop at intervals for over half a mile down-stream from the section just described are last seen, 8 ft. of coal (floor below water-level and not seen) appears on the west bank of the Waimangaroa. The high cliff-face above is formed of grit and sandstone, containing a thin coal-seam near the top. On the east side of the river, some chains to the north and about 70 ft. above the bed, 2 ft. of coal (floor not seen), with a roof showing 5 in. of sandstone overlain by grit, is exposed. The seam may be of workable thickness, and is doubtless the same as the 8 ft. coal below. It strikes 291°, and dips at 11° to the west of south.

The coal outcropping near the Kiwi Compressor and now being worked by the Westport Coal Company is of moderate thickness only. Down-stream the seam increases greatly in size, and is accompanied by other seams, which are probably splits. Owing to dense fog at the time of an inspection by one of the writers no sections were obtained. Denniston's sections, Nos. 96, 97, and 98 (page 154 of his report) refer to this locality, but do not give full information concerning the coal-seams, possibly because talus from the cliffs hides or partly hides some of the outcrops.†

* On Cooper's map two coal-outcrops numbered 80 are shown. The more southerly is in the position of the section described: the other is probably Denniston's section No. 79.

† In a hand-coloured map in the Geological Survey Office (probably Denniston's work) section No. 98 is shown as near where the Kiwi air-compressor and other plant now (1913) stand. Its proper position must be some distance down-stream.

At the junction of Hut Creek with the Waimangaroa, opposite Deep Creek, very thick coal is exposed, though Denniston's estimate of 40 ft. (section No. 95) at this point (Denniston Falls) is probably over the mark.

As a whole the upper Waimangaroa area holds a considerable amount of coal, the greater part of which is contained in the strip, fairly wide to the south, that adjoins the Mount William fault. In the watershed of Deep Creek, and on the higher slopes of Mount Frederick, the coal is apparently in patches, separated by areas of erosion, or in some cases by ground in which the coal has thinned or been replaced by shale.

Adjoining the Kiwi fault is a debatable area in which appearances on the whole suggest that the thick coal seen in the neighbourhood of Waimangaroa River both thins and reaches the surface, but it is possible that the small coal-seam outcropping east of the fault is either quite separate or a split from the main body. Before sound conclusions can be reached bores on both sides of the Kiwi fault are necessary. The matter is of great importance in connection with the area of approximately 1,200 acres commonly known as Cook's lease, and to a less extent in connection with the Westport Coal Company's ground. Some positive evidence favouring the existence of a lower workable seam is found south of the head of L 75 Creek, where in a deep gully draining to Deep Creek a body of coal over 4 ft. thick with shale roof and floor outcrops beneath fully 150 ft. of grit. To the east, however, and perhaps also to the west, the coal thins. Whether it thickens to the south remains to be seen.

(8.) *Denniston-Cascade Creek Area.*—The Denniston-Cascade Creek area forms the central eastern part of Kawatiri Survey District. It may be regarded as bounded on the north by the Waimangaroa gorge, on the east by the Ngakawau Survey District and the Mount William fault, on the south mainly by the cliff-faces overlooking Cascade Creek valley, and on the west by a line drawn from Denniston to where Trent Creek enters the Whareatea, and thence continued southward to the boundary of the coal-measure rocks. With the exception of Cascade Creek valley and the gorges of the various streams, this area has a gently rolling surface, portions of which are almost flat. Hence the local name of Denniston or Coalbrookdale Plateau for the district, as mentioned in Chapter II (page 31). As elsewhere in the uplands, the prevailing rocks are grit and sandstone poorly hidden by thin peaty soil supporting a scanty vegetation. The northern and eastern parts of the area atone for the poverty of their surface by their richness in coal of the finest quality, but the central and western portions are barren in every way.

Immediately east-south-east of Denniston township several small coal-seams outcrop in the cliff-faces overlooking the Waimangaroa Gorge. The largest of these, probably not more than 4 ft. thick where first seen, increases in size to the eastward, and was worked many years ago by the owners of the Fisher or Banbury Mine (Westport Colliery Company—later the Westport Coal Company). South-westward the coal apparently thins out, probably against the old surface of the Aorere rocks ("slates"). Near Burnett's Face, on both sides of Burnett Creek to its mouth, and thence in the gorge of the Waimangaroa eastward to Deep Creek, many fine outcrops of thick, hard, and clean coal may be seen. In one part of the cliff-face three bands of coal, which may be regarded as splits from the one main seam, are visible.*

In a report made in 1863 James Burnett† gives an account of the coal-outcrops in or near the upper part of the Waimangaroa gorge. The two following sections.

* See No. 1 of Burnett's sections, quoted on the next page.
† "Report on Part of the Grey Coalfield North of the Buller River": *Nelson Gazette*, vol. xi, No. 8, 20th April, 1863.

although they cannot be exactly located without the aid of Burnett's unpublished map, are worth quotation :—

1.	Ft.	in.
Grit and sandstone	49	0
Sandstone and shale	32	0
Grit	27	0
Grit, sandstone and shale	34	0
Sandstone	22	0
Coal and shale	19	0
Sandstone	9	0
Coal and shale	12	0
Grit	42	0
Coal	5	6
Shale	5	0
Yellow sandstone	20	0
Slaty rock		

2.	Ft.	in.	Ft.	in.
Grit and sandstone				
Soft fine-grained sandstone ..			4	0
Hard white sandstone			15	0
Grit			16	0
Hard white red sandstone ..			2	2
Coal	3	3		
Shale	0	3		
Coal	4	6		
Shale and coal	0	5		
Coal	5	7		
Shale	0	1½		
Coal	1	3		
Shale	0	4		
Coal	1	0		
			16	8½
Fine-grained grey sandstone ..				

No. 1 section, which was observed by Burnett "from a distance," is probably near the junction of Burnett Creek with the Waimangaroa. To the south "these beds join and form one large seam," giving section No. 2, at 1,692 ft. above sea-level.

Near Burnett's Face, on the road to Kiwi Compressor, good sections of the grits and sandstones overlaying the coal may be seen. Close to the bridge that gives a name to the Ironbridge Mine the section seen is: 25 ft. of grit, underlain by 8 ft. sandstone and shale, 2 ft. coal, 4 ft. or more of shaly rock, 1½ ft. fine sandstone merging into shale, many feet of coal (see Fig. 15A).

A few chains to the south-east the main coal-seam completely thins out against a pre-Tertiary surface of bleached argillite. The section is: 36 ft. grit, sandstone, and shale; 6 in. coal; 3 ft. shale; 12 ft. sandstone; 2 ft. grit, thinning out on left; 3 ft. shale; 3 ft. sandstone; 6 ft. grit; 3 ft. coal, thicker on left, thinning completely out on right; 1½ ft. shale, thinning out to 2 in. or 3 in. on right; 20 ft. argillite. The coal-measures strike 320°, and dip 10° to 20° to the north-east. The Palæozoic argillite has nearly the same strike, and a dip, only slightly steeper, in the same direction: thus there is almost an appearance of conformity for a few yards (see Fig. 15B).

The road-cuttings to the eastward show some fine examples of current bedding in the sandstones and grits overlying the coal (see Figs. 16A and 16B). In various places a small upper seam of coal 5 in. or 6 in. thick is exposed, but the lower seam is everywhere under cover.

From Burnett's Face to Coalbrookdale coal outcrops almost continuously on the east side of Burnett Creek. The coal in one or two places is interbanded with shale, and inclines to be thin, among the observed thicknesses being 2½ ft., 6 ft., and 5 ft. (see also Denniston's sections 109, 110, 118, 111, and 113). At Coalbrookdale itself the observed thickness is from 5½ ft. to 12 ft., with the floor generally not visible (see also Denniston's sections 121, 114, 112, and 122). The coal is hard, and of splendid quality, especially in the mine-workings. The roof is generally sandstone, but in places is much less desirable shale.

On the western side of Burnett Creek south of Burnett's Face there is very little coal, the seam thinning very much, and in places apparently disappearing altogether. In any case the coal-bearing horizon is largely denuded, so that between Coalbrookdale and Denniston patches of pre-Tertiary rocks appear on the surface.

In the cliffs south of Coalbrookdale overlooking Cascade Creek valley thick clean coal is exposed in many places. The outcrops show 12 ft. to 25 ft. of coal, and occur at heights ranging from 1,800 ft. to 2,350 ft. The roof is generally sandstone or grit, disposed almost horizontally.

The greater part of Cascade Creek valley is devoid of coal-measures, but towards its head the downward movement caused by the Mount William and some nearly parallel faults has preserved from complete denudation a patch which at its north-east end is continuous with the main area. Though the coal-outcrops seen here are thin (2 ft. to 6 ft.), lower down the creek coal from 15 ft. to 20 ft. thick is exposed. Denniston reports many outcrops from 20 ft. to 40 ft. thick, but probably his estimates are in most cases over the mark. For instance, the outcrop near the mouth of Hagen Creek stated by him to be 30 ft. thick (section No. 167, page 168 of report) appears to be only 20 ft. or so in thickness, a dimension, however, that is by no means to be despised, especially since the coal is of good quality.

The Cascade Creek coal is somewhat shattered, and in places completely crushed, but is clean and otherwise of good quality. The coal-bearing area is small, and it is doubtful whether the Westport Coal Company, which holds most of the ground, and is now working the upper or northern portion, will find it worth while to extract the coal near the southern end. The locality has been fully described and mapped by Cox, Denniston, and Cooper, under the name of Todea Creek.* Owing to the non-recognition of faulting, Cox's boundaries do not quite coincide with those shown by the maps accompanying the present report. This statement, however, is not intended to imply that the new boundaries are rigorously accurate.

West from Coalbrookdale towards the Whareatea the coal thins and in many places has a treacherous shale roof. Apparently workable outcrops may be seen in the Upper Whareatea, and occur at wide intervals for some distance down the narrow valley of the stream. The best of these latter exposures is in the stream-bed close to V 40 Creek junction, at a height of 2,030 ft. above sea-level. The coal is here of very good quality, and of workable though undeterminable thickness. About a quarter of a mile to the north-west of this occurrence coal several feet thick is visible on the north side of the Whareatea. To the westward only carbonaceous shale, with thin coaly layers, is observable. (See also Denniston's sections Nos. 127 and 128, page 161 of his report.)

(9.) *Lower Waimangaroa Area.*—The Lower Waimangaroa area may be defined as including the sloping ground from Stony Creek to Waimangaroa, and thence to the Whareatea River. Throughout this area the coal-measures have in general a westerly dip exceeding 25°, and towards its western margin become thoroughly involved in the Lower Buller or Kongahu fault-zone. According to Denniston and Cooper the coal-bearing portion of the area is no less than 1,200 acres, but this includes a portion of the coastal plain, and much ground where no workable outcrops can be seen. The proved coal-bearing ground is by no means of great extent, while the coal is throughout broken, crushed, and frequently "sooty," as may be judged from Denniston's report. Some distance up Kiwi Creek, at a height of about 400 ft., a large amount of coaly material is visible in the débris on the south bank. This is the locality of Denniston's outcrops No. 150, erroneously recorded as in Stony Creek. Somewhat to the northward, on Organ's Spur, Denniston notes other coal-outcrops, one being 30 ft. thick (sections Nos. 151 and 152, pages 131, 165, 166 of his report).

Less than a quarter of a mile south of Waimangaroa Village railway-station coal outcrops a few feet above the railway to Conn's Creek. Appearances are quite consistent

* Rep. G.S. during 1874–76, No. 9, 1877, pp. 109–11, &c. The name Todea Creek seems to have been given owing to some misapprehension concerning the position of Cascade Creek.

with a thickness of 30 ft. The coal here strikes 214°, and has a north-westerly dip of 60°, lessening somewhat to the south-east. It was prospected in early days by Sims and by Roche, and during the years 1891–92 worked by Young and Haylock. There were five levels, No. 1 being the lowest, of which No. 4 was Roche's drive, in which Denniston reports 18 ft. of coal, with a westerly dip of 40° (section No. 147). At the points where Young and Haylock's workings ended the coal had thinned, it is stated, to 2 ft. owing to a roll. Beyond this the probability is that the coal again thickens. Unfortunately the coal is much crushed, and therefore, though not high in ash, is of a quality not profitably saleable at the present time.

East of Young and Haylock's workings, and on the other side of the Waimangaroa River, is the old Wellington Mine, first prospected, it would seem, by Sims and Mulholland. According to Denniston, Sims's (or Mulholland's) drift cut coal 18 ft. thick, evidently of a crushed and sooty (" blind ") character.

On the slope of Sims Spur, overlooking the Waimangaroa, near which the Koranui incline was afterwards constructed, Denniston noted various outcrops of coal (Nos. 149, 153–57) varying in quality, but all, except No. 149, of great thickness. Probably, therefore, this part of Sims Spur is worthy of careful reprospecting.

On the bridle-track from Waimangaroa Village to Denniston, at a height of 645 ft., a seam showing over 8 ft. of clean but somewhat crushed coal is exposed. It is underlain by 12 ft. of black micaceous mudstone followed by coarse arkositic grit. The coal strikes 216°, and dips at 45° to the north-west.

On the road from Waimangaroa to Denniston at various points from approximately 650 ft. to 1,900 ft. or more in elevation, outcrops of crushed, sooty, and in places dirty coal appear. These are of moderate thickness only, and dip north-west or west-north-west at angles from 40° downwards. The enclosing rocks are, as usual, grit, sandstone, and shale.

On the whole, the coal of the Waimangaroa area does not give much promise of being again worked in the near future. The coal, though thick, is extremely crushed and "sooty," and at the present time could hardly be used for any other purpose than the manufacture of coke. To the south-westward of the Waimangaroa–Denniston Road the coal seems to become very thin, and ultimately quite disappears, but possibly this is the result of denudation rather than of an original absence of coal from the strata. Indirectly, the thick coal near Waimangaroa Village is of some value, since it indicates the probability of workable coal at depth beneath the Westport flats.

10. *Mount Rochfort Area.*—The Mount Rochfort area may be defined as the somewhat extensive district covered by coal-measures that lies south-west of the Whareatea River with its tributary Trent Creek, and extends almost to the Buller River. Mount Rochfort (3,382 ft.) is its culminating-point, whilst on the lowest slopes of that mountain and near the Buller it is not far above sea-level. On the whole it is an almost barren area, large portions having been originally devoid of workable coal, and other portions having lost nearly all their coal through denudation.

At the head of Conglomerate Creek, at a point about 2,600 ft. above sea-level, a band of carbonaceous shale containing some impure coal is visible. In this locality Denniston gives a section (No. 133) with 6 ft. of coal, but no such outcrop was observed by the members of the Geological Survey party. Hence to the summit of Mount Rochfort no coal can be seen. On the map with manuscript additions previously mentioned is marked a series of outcrops (numbered 141 to 143) somewhat below the base of the high cliffs that trend eastward from the summit of Rochfort. Presumably these outcrops correspond to the somewhat elaborate sections with the same numbers given by Denniston in his report (page 164), from which it appears that two small coal-seams are exposed. Owing to the locality being bush-clad and very difficult of access, it was not re-explored by the Geological Survey party. Further investigation seems desirable, though commercial results need not be expected.

Of two further outcrops, presumably of coal, shown in manuscript on the map mentioned above, one is nearly three-quarters of a mile south-west, and the other 12 chains north-west, of the trigonometrical station on Mount Rochfort.

In the upper part of Christmas Creek (Fairdown), at a height of about 1,000 ft., dark shale with coaly bands and much loose crushed coal are visible. A small branch which now receives the overflow of Lake Rochfort exposes some loose coal on its banks, and near the shores of the lake small coal-seams associated with grit and sandstone outcrop.

On the track leading to Lake Rochfort, not far above the coastal plain, broken coal belonging to a small seam is exposed.

In Deadman Creek, at a height of about 480 ft., loose coal appears in the gravels of the terrace bordering the stream, but no outcrop has been found in this locality.

In Wright or Coal Creek, which flows westward from trig. station M, a point on the ridge trending south-west from Mount Rochfort, are indications of coal similar to those in Christmas Creek. At approximately 790 ft. and 1,025 ft. loose crushed coal is abundant on the banks of the stream.

West Creek, south of Wright Creek, shows similar unsatisfactory coal shoadings at points high up its valley. Apparently on the strength of these, two bores have been drilled in search of coal (see also page 186).

The Mount Rochfort area may be regarded as entirely worthless from a mining standpoint. Its coal shoadings and carbonaceous shale outcrops are of value only as indicating the possibility of workable coal beneath the flats extending northward and westward from the neighbourhood of the Nine-mile Ferry (Te Kuha), the Orowaiti terraces, &c.

(11.) *Northern Part of Mount William Range and Head of Erin Creek.*—Between the Upper Blackburn Valley and the northern part of the Mount William fault is a broken hilly country of moderate elevation, in part clad by low forest, in part open, more especially on the ridges. This district, in accordance with the general structure of the Papahaua earth-block, has an easterly tilt, but the drainage is to the north-north-east, mainly into Erin Creek, and thence to St. Patrick Stream. From it the bituminous coal-measures have been very largely removed by denudation, but besides numerous minor remnants of the lower grits and sandstones there remains an L-shaped strip of coal-measures which extends south-south-west from St. Patrick Stream to trig. station AF, and thence east-south-east to the Blackburn pakihi. This area shows a number of workably thick outcrops of good coal, but these are far from being continuous, so that the coal is in comparatively small patches, of little interest from a mining standpoint.

In order to illustrate the outcrops one or two of the best sections may be given. East of the upper part of Darcy Creek, at a point 50 chains east of trig. AF, over 12 ft. (perhaps 16 ft.) of good clean coal outcropping at a height of approximately 2,120 ft. is overlain by many feet of coarse sandstone and grit containing thin coal and shale seams. The floor as seen is 3 ft. of shale, resting on coarse grit approaching a conglomerate. These beds have a gentle dip to the north-north-east. An analysis of the coal is given on page 139.

Thirty chains to the south-west the following section is visible: 6 ft. sandstone, underlain in order by 5 ft. shale, 10 ft. coal, 3 ft. shale, 6 ft. sandstone, 20 ft. grit, 6 ft. shale and fine sandstone with thin seams of coal, 20 ft. grit, 6 ft. sandstone with a thin coal seam, and 20 ft. grit. The total thickness of the exposed section is thus somewhat over 100 ft. Not far away coarse basal conglomerate, capped by grit, outcrops.

The somewhat flat ridge forming the northern part of the Mount William Range, and having trig. AF (2,700 ft.) as its highest point, shows everywhere outcrops of coal-measure grit. Small portions of the ridge contain coal of good thickness and quality, but the remainder, probably owing to denudation, is apparently devoid of workable coal.

The main seam of coal in the area just described may tentatively be regarded as the Matipo seam, and the smaller seams as splits from it.

(12.) *Central and Southern Parts of Mount William Range.*—Southward from the saddle half a mile south of trig. AF the coal-measures have been entirely removed by denudation for a distance of over two miles and a half. Near Wilson Saddle a coal-bearing outlier extending for some distance to the east begins. Close to the saddle is the following section: 12 ft. grit, underlain in order by 12 ft. sandstone, 10 ft. shale, 8 ft. of friable but clean coal (height 2,190 ft.), 15 ft. shale with coaly layers near the top, and finally grit separated by a few feet of unknown material from the overlying shale. The coal is in a somewhat narrow ridge, and occupies no great area.

The only other observed outcrop in the outlier worth note is a mile to the eastward, where, at an elevation of 1,480 ft., at a point crossed by the foot-track to the Mackley, an outcrop of hard coal at least 8 ft. in thickness is visible with difficulty in a fissure almost hidden by vegetation. A few feet above the coal grit is exposed, so that this rock probably forms the roof.

Between Wilson Saddle and Mount William are several other outliers of the bituminous coal-measures, but none of these contains any coal of importance. Mount William itself is capped by a considerable coal-bearing outlier approximately 110 chains long and 21 chains in average width which lies at heights of from 2,800 ft. to 3,482 ft. above sea-level. The area as measured by planimeter is 234 acres, of which 180 acres probably contains coal of workable thickness. The coal as seen on the margin of the outlier is from 6 ft. to over 20 ft. thick, but is friable and in places somewhat dirty. Denniston's sections (Nos. 102 to 108, pages 155–57 of his report) show a maximum thickness of 40 ft. of coal. This, however, is probably an over-estimate. The immediate roof of the coal in many places is shale, above which comes a considerable thickness of sandstone and grit with one or two small coal-seams.

Towards the north-east of the outlier the Mount William coal becomes thin, and when its somewhat poor quality, isolation, and height are taken into account, it would appear that the working of the area is not at present feasible. This remark, however, cannot be held to apply to the future, for when the better and more easily accessible Coalbrookdale coal is exhausted, attention will be turned to Mount William.

(13.) *Omanu (Back) Creek or Moran's Water-race Outcrop.*—The only indication of bituminous coal for many miles south of the Buller is seen near Omanu Creek at the point where it enters gneissic country and is crossed by the Lower Buller fault. On the north side of the stream, at a point 610 ft. above sea-level, a drift, now in bad condition, has been driven for a short distance, and probably enters Eocene coal-measures. The tip shows a considerable amount of broken and crushed bituminous coal. On the south side of the stream, 80 ft. up the slope, and just above Moran's (now McCann's) water-race, another drift, now entirely collapsed, has been made. Completely crushed coal shows on the steep hillside at this point, and though perhaps not strictly in place, may be considered to represent an outcrop. With it is associated a few feet of grit of Eocene facies, which strikes south-west, and has a vertical dip. Any further exploration of this outcrop is quite unnecessary. It is merely a fault-involved fragment of the bituminous coal-measures, and therefore indicates their westerly extension beneath the lowlands, but is otherwise valueless.

Coke and Briquettes.

The Westport bituminous coals as mined usually make hard firm cokes, suitable for most metallurgical processes. As a whole they are too high in sulphur to make the best class of coke for foundry-work and iron-smelting, but by selecting the best faces this disadvantage may be partly avoided. In the coking process nearly half the sulphur in the coal seems to be eliminated. At this point mention may again be made of the natural coke found on the south bank of Chasm Creek, near Dove's drive.

Analyses of coal used for coking and of artificial and natural coke are as follows:—

	(1.)	(2.)	(3.)	(4.)	(5.)	(6.)
Fixed carbon	64·25	96·93	97·16	94·45	98·18	91·54
Volatile hydrocarbons ..	33·91	0·70	0·96	0·94	0·62	2·97
Water	0·81	0·13	0·11	0·21	0·16	2·19
Ash	1·03	2·24	1·77	4·40	1·04	3·30
Totals	100·00	100·00	100·00	100·00	100·00	100·00
Total sulphur per cent. ..	0·78	0·71	0·68	2·67	1·05	3·44
Calories per gram ..	8,411	7,727	7,767	..	..	7,349
B.t.u. per pound.. ..	15,140	13,908	13,981	..	..	13,228
Phosphorus per cent. ..	..	0·036	0·018	..	0·009*	..
Total arsenic in parts per million	..	4 to 6	4 to 6	..	4 to 6	..

(1.) Crushed coal from Millerton Mine, used for coke and gas making. Lab. Rep. No. 46, 1913, p. 11.

(2.) Coke in lumps, representing an average of several ovens (Granity). Lab. Rep. No. 46, 1913, p. 11.

(3.) Coke (crushed) from No. 2. Lab. Rep. No. 46, 1913, p. 11.

(4.) Coke, Millerton Colliery (Granity coke-ovens). Lab. Rep. No. 46, 1913, p. 13.

(5.) Coke, Granity coke-ovens. Grab sample.

(6.) Natural coke, Chasm Creek. Single lump.

The ash of the natural coke (No. 6) has the following composition:—

Silica (SiO_2)	26·74
Alumina (Al_2O_3)	11·50
Iron-oxide (Fe_2O_3)	53·84
Manganese-oxide (MnO)	0·80
Lime (CaO)	3·16
Magnesia (MgO)	0·54
Mixed alkalies (K_2O, Na_2O)	1·35
Titanium-dioxide (TiO_2)	0·92
Vanadium	Nil
Undetermined (? carbon)	1·15
	100·00

* Phosphoric anhydride 0·021 per cent.

The following are analyses of briquettes and eggettes made from Seddonville slack with the addition of pitch at the Westport works:—

	(1.)	(2.)
Fixed carbon	48·84	46·93
Volatile hydrocarbons	41·46	42·05
Water	5·54	8·03
Ash	4·16	2·99
	100·00	100·00
Total sulphur per cent.	3·62	3·74
Calories per gram	7,249	6,969
B.t.u. per pound	13,048	12,544
Theoretical evaporative power in pounds of water at 212° F.	13·53	13·00

Reference: Lab. Rep. No. 43, 1910, p. 7.

II. BROWN COAL AND LIGNITE.

General Description.

The lower horizon of the Oamaru Series in most localities contains one or more seams of brown coal, which may, on the one hand, approach a pitch or even a bituminous coal, and, on the other, grade into lignite with over 20 per cent. of water. The coal in places is very thick, but there can be no doubt as to its lenticular nature. If this feature is not duly appreciated, overestimates of the quantity of workable coal in any given area will result.

The brown coal of the subdivision occurs principally in two localities—Charleston, and those parts of the Buller Valley adjacent to the Inangahua district. Outcrops are also known at Tauranga Bay and near Cape Foulwind. East of Hawk's Crag very thin seams of dirty coal, almost bituminous in composition, appear in a horizon lower than that of the main brown-coal seam. No coal has been found in the Miocene rocks between the Mokihinui River and Karamea, except the thin and dirty seams of lignite reported by Webb as occurring in the Upper Kongahu Formation just to the north of the area mapped by him, and doubtfully outcropping within the Mount Radiant Subdivision itself.* In a similar horizon is some lignitic material penetrated by the Westport Harbour Board's bore near Addison's Flat.

Physical Characters.

The brown coal or lignite at Charleston and Tauranga Bay is of somewhat dull appearance, and when exposed to the sun and weather, like other similar coals, soon disintegrates. The freshly mined material, however, is compact, and stands ordinary handling very well. The Buller Valley coal is of better appearance than the Charleston lignite, lustrous bands being much more prominent. As a rule it is compact, and resists weathering to a considerable extent, though in this respect it is not to be compared with the bituminous coals.

Resin is a prominent constituent of the brown coals, especially at Charleston.

Chemical Composition.

The thin lignite-deposits near Cape Foulwind contain a very high percentage of water. The thicker seams in the same horizon at Tauranga Bay, less than two miles

* N.Z.G.S. Bull. No. 11, 1910, pp. 21, 40.

away, are considerably lower in water, and are quite serviceable for household use. Sulphur, however, is high. The coal mined at Charleston is very similar in composition to the Tauranga Bay material, the water approaching 20 per cent., and the sulphur lying between 5 and 6 per cent.

The brown coal of the Buller Valley has been subjected to a greater amount of earth-movement than the Charleston coal, and this is probably the reason why the former is on the whole of decidedly better quality, being higher in fixed carbon and lower in water. Its sulphur-content is also less.

Analyses.—In the following table are quoted a number of analyses of the Miocene coals made at various times:—

Number.	Locality.	Fixed Carbon.	Volatile Hydrocarbon.	Water.	Ash.	Sulphur.	Remarks and Reference.
1	Charleston	40·82	33·16	21·09	4·93	..	Average analysis given by S. H. Cox in "Notes on the Mineralogy of New Zealand," Trans., vol. xv, 1883, p. 367.
1A	Darkie Creek, Charleston	38·26	40·51	20·41	0·82	..	Collected by A. McKay. Lab. Rep. No. 29, 1895, p. 6. Analyst, W. Skey.
2	Charleston	41·02	30·22	24·61	4·15	..	Per Mr. Blaine, Charleston. Lab. Rep. No. 30, 1897, p. 6. Analyst, W. Skey.
3	"	33·55	44·53	19·17	2·75	6·00	Sample collected by Geological Survey.
4	"	32·53	46·43	18·81	2·23	5·40	Average of four samples from different pits collected by Geological Survey.
5	Tauranga Bay ..	36·75	38·20	19·20	5·85	5·57	Calories 4987. Sample collected by Geological Survey.
6	Cape Foulwind ..	26·83	35·31	18·24	19·62	..	Forwarded by Mr. A. D. Bayfeild, as taken from under 6 fathoms of water. Sea-shells embedded in it. Lab. Rep. No. 29, 1895, p. 4. Analyst, W. Skey.
7	Cape Foulwind (cliffs) ..	33·90	28·00	30·00	8·10	..	Analyst, H. Lovell, Director Westport School of Mines.
8	Station 38, Nada Creek ..	34·40	35·75	19·37	10·48	3·77	Collected from 1 ft. 10 in. coal-seam by Geological Survey. Ash, grey in colour.
9	Station 46, Nada Creek	37·60	38·67	18·65	5·08	4·28	Collected from large coal-seam by Geological Survey. Ash, light grey.
10	Station 5, Zulu Creek ..	40·28	40·05	15·36	4·31	4·06	Collected from large coal-seam by Geological Survey. Ash, light grey.
11	Pensini and Slug creeks	40·58	43·30	11·01	5·11	3·67	Average of six samples collected by Geological Survey.
12	Blue Duck Creek, near station 43	52·50	40·50	5·60	1·40	..	Firm grey coke with metallic lustre. Sample collected and analysed by J. V. Kitto (member of Geological Survey party).
13	Blue Duck Creek, near station 43	49·36	42·38	7·81	0·45	3·99	Collected by Geological Survey. Specific gravity 1·28. Calories 7,004. Forms a firm swollen coke.
14	Blue Duck Creek, between stations 79 and 80	36·48	43·99	3·05	16·48	0·71	Collected by Geological Survey. Specific gravity 1·34. Calories 6,442. Forms a soft coke.
15	Inangahua Survey District	40·77	42·74	12·54	3·95	4·55	Average of eleven samples collected by Geological Survey in 1913 and 1914.
16	Near Hawk's Crag ..	64·06	11·59	10·14	14·21	..	Soft and intensely black coal; does not cake. Lab. Rep. No. 29, 1895, p. 5. Analyst, W. Skey.
17	Near Hawk's Crag ..	54·73	20·86	7·19	17·22	0·50	Non-caking. Collected from small seam by Geological Survey.

Origin.

The facts observed in connection with the bedding and other characters of the brown coals favour the drift theory rather than that of growth *in situ*. The chief observations connected with the question of origin may be summarized as follows:—

1. The coal-seams are highly lenticular. This features is especially prominent near Charleston.

2. Lumps of resin, which are apparently transported, occur in many places.

3. At Charleston large flinty concretions and balls of clayey material are abundant in the coal. Lenticular shaly bands are also a prominent feature.

4. Sea-shells are reported as occurring embedded in lignite obtained by dredging near Cape Foulwind.* This, if correct, would imply that the lignite was deposited under marine conditions. Mr. A. D. Bayfeild, however, who forwarded the sample to the Colonial Laboratory, has been kind enough to inform one of the writers that, so far as he recollects, seaweed and shells were adhering to the outside, a circumstance which, of course, is without significance in connection with the question of origin.

Detailed Description of Outcrops.

(1.) *Charleston District.*—About a mile south of the Four-mile Stream, on the eastern side of the bridle-track leading to Brighton, at least 4 ft. of lignite outcrops. There is here an outlier of the Miocene coal-measures, somewhat over half a mile long, but probably less than 20 chains in maximum width. It rests on gneiss, which outcrops on three sides, but on the fourth is hidden by high-level auriferous gravels.

Somewhat to the north of Four-mile Stream is a much larger outlier of Miocene rocks, again resting on gneiss. This exhibits near the eastern side of the Brighton-Charleston Road several outcrops of workably thick lignite.

About a mile and a quarter to the south of Charleston, and east of the Brighton Road, a third small gneiss-surrounded outlier of the brown coal or lignite measures appears. Here the following section is visible: Soil and gravel, underlain in order by 2 ft. shale, 6 in. lignite, 4½ ft. shale, 1½ ft. lignite, 1 ft. or more of shale, 3 ft. to 4 ft. lignite, a considerable thickness of light-brown shale, and finally a nearly white rock, probably sandstone (see Fig. 17). To the south of this section the main coal-seam thickens, whilst 3 ft. below it a small lignite-seam makes its appearance, and, owing to the thinning of the intervening shale, approaches within a foot of the main body before being lost to sight.

About half a mile to the north-east of the last-mentioned area, in Victoria Gully, thin lignite-seams striking 236° and dipping at 8° to the south-east† may be seen. A second observation in the same locality gives a dip noted as 12° or over.

Immediately south of Charleston lignite is close to the surface over an area of approximately 80 acres, and has been worked by means of numerous open pits for local use. As disclosed by these workings, the coal is from 6 ft. to 20 ft. thick, but in no case is the floor seen. The seam lies nearly horizontal, and only in one or two places does it show a gentle south-easterly dip. The roof in one pit consists of a foot or two of brown marine sandstone, overlain by soil, whilst in another working there is a variation from cemented to loose sand. These roof-rocks join the coal in a somewhat irregular manner, and are almost certainly unconformable Pleistocene sands, the original Miocene cover having been removed by erosion. As shown by sections elsewhere, the normal coal-roof is shale. The occurrence illustrates an unconformity that is difficult to detect.

* Twenty-ninth Annual Report of the Colonial Laboratory, 1895, p. 5.

† On the map the dip has been plotted in the wrong direction according to the field-notes taken in this locality.

East of Charleston, near Darkie Creek, thick coal outcrops, and for many years was worked as the "Charleston Mine." North of the township, and on the west side of the road to Westport, is Warne's pit. The coal outcropping near the road rests on shale, below which is grit, and is unconformably overlain by beach-sands. The coal-bearing rocks have a gentle but varying dip, in one place northward, in another southward.

South of west from Warne's pit, near the shore of Constant Bay, the following section is shown in a low cliff: Light-coloured shale, underlain by 5 ft. to 6 ft. lignite, 2 ft. to 3 ft. light-coloured shale, 2 ft. to 3 ft. lignite, a few feet of shale, current-bedded sandstone, and grit passing into conglomerate (see Fig. 18A). A few chains to the northward is the highly variable section illustrated by Fig. 18B.

The following analyses of moderately air-dried samples of Charleston brown or lignitic coal may be quoted :—

	(1.)	(2.)	(3).	(4)	(5.)
Fixed carbon	34·43	31·88	31·11	30·56	36·55
Volatile hydrocarbons	44·31	49·91	47·64	46·91	41·27
Water	19·40	15·92	19·15	18·92	21·26
Ash	1·86	2·29	2·10	3·61	0·92
	100·00	100·00	100·00	100·00	100·00
Total sulphur per cent.	5·17	5·60	5·22	5·66	5·11
Calories per gram	..	5,615	..	..	..
B.t.u. per pound	..	10,107	..	..	..
Specific gravity	..	..	1·27	1·27	..

(1.) Average of nine samples from various outcrops. See Dom. Lab. Rep. No. 46, 1913, p. 13. Some samples on being heated in a closed vessel fritted or gave a soft pulverulent coke.
(2.) From Sweeney's pit—First sample.
(3.) From Sweeney's pit.—Second sample.
(4.) From Lavery's pit.
(5.) From Warne's pit.

An ultimate analysis of the first sample from Sweeney's pit gave the following results :—

Carbon	56·30
Hydrogen	6·15
Oxygen	29·20
Sulphur	5·60
Nitrogen	0·46
Ash	2·29
	100·00

Ferric oxide in ash	0·11 per cent.
Calories per gram as calculated from analysis	5,536
Soluble in pyridine (approximately)	17·2 per cent.
Soluble in carbon-bisulphide	1·2 per cent.

Concerning the sulphur in the above sample the analyst remarks, "The lignite emits sulphuretted hydrogen on being distilled. It contains a trace only of soluble sulphate. Judging from the carbon-bisulphide extract, which was a hard, resinoid substance, little if any free sulphur is present. The maximum amount of iron-pyrites, assuming that all the iron in the ash is combined with sulphur, would be 0·17 per cent. The resin separated from the coal [see page 180] contains a smaller percentage of sulphur than the coal itself—namely, 3·04 as against 5·60 per cent. It is evident, therefore, that the sulphur is combined organically in the non-resinous portion of the lignite."*

Proximate analyses of other samples of Charleston coal are given in the table on a preceding page (Nos. 1–4).

Tests of samples 4 and 5 were made in order to ascertain if gold were present. No. 4, from Sweeney's pit, was found to contain 0·7 gr. of gold per ton, but No. 5, from Lavery's pit, gave a negative result.

The Charleston lignite on the whole has a dull appearance, but on close inspection shows thin layers of bright material, together with more or less resin as already described. Though high in water and sulphur, the coal is valuable for local use. Being easily and inexpensively mined from open pits, it is retailed in Charleston for a few shillings per ton. The water-content can be reduced by storing under cover for some time, but if exposed to sun and weather the coal, like other lignites, cracks extensively, and ultimately falls to powder.

In most localities the coal exhibits dirt bands and partings that may either thin out in a short distance, or on the other hand pass into shaly bands of some thickness. As seen in one pit it contains numerous bluntly lensoid inclusions of clay and shale, the largest of which are one or two feet in thickness and several feet in length. With these are associated more or less rounded flinty bodies reaching diameters of over a foot. Some flinty matter also occurs in the shaly lenses. The coal in the neighbourhood of some of the larger inclusions contains small patches of clay that recall to mind the "spotted coal" found near the roof in some parts of the Green Island district, Otago.

The Charleston coal, like most lignites, is very easily ignited, and is moreover liable to spontaneous combustion. Since much of the coal-bearing land is overrun with gorse, it is not surprising that outcrops have been set on fire several times. So far, however, these fires have been extinguished without serious damage being done.

(2.) *Cape Foulwind and Tauranga Bay.*—In the railway-cutting near Cape Foulwind a thin gritty carbonaceous band is visible, interbedded with fine conglomerate and grit resting on gneissic granite. A short distance to the south-east, in the cliff facing the beach, are two thin irregular seams of dull-looking lignite, and it is reported that a third small seam, probably corresponding to that seen in the cutting, is at times exposed on the beach. The section shown by the cliff is: 30 ft. of marine mudstone with limestone bands, underlain by 40 ft. soft grit, 1 in. to 4 in. lignite, 6 ft. grit, 3 in. (more or less) of lignite, 40 ft. or more coarse grit. These beds strike north and south, and dip at 15° to the east. An analysis of the lignitic material is given in the table on page 173 (No. 7). It is hardly necessary to point out how different this hydrous low-grade coal is from the magnificent bituminous fuel mined in the upland country, and that on the ground of chemical composition alone correlation (*pace* McKay) between the Cape Foulwind and Denniston beds is highly improbable.

On Tauranga Bay beach, at the point where a small stream enters the bay, several seams of fairly good and bright-looking lignite are exposed whenever the beach is sufficiently washed clear of sand. On the 19th October, 1912, four seams were more or less visible, the lowest, about 3 ft. thick, being underlain and overlain by dark shaly rocks, with a strike of 178°, and a dip of about 5° to the east. The next seam, 3½ ft. thick, contained a good deal of resin, and was overlain by dark shaly sandstone. The

* Lab. Rep. No. 47, 1914, p. 15.

other two seams were each apparently over 1 ft. in thickness. Analysis No. 6 in the table on page 173, represents the lowest seam exposed on the date mentioned.

(3.) *Thin Seams near Hawk's Crag.*—A quarter of a mile north-north-east of Hawk's Crag two small coal-seams outcrop within a few yards of each other on the eastern side of the Buller Gorge Road. They are mentioned by McKay in one of his reports.* The larger seam, about 8 in. in average thickness, consists of crushed and somewhat impure sooty coal, low in volatile matter, as is shown by analyses Nos. 16 and 17 on page 173. The interbedded strata are shale, sandstone, and fine conglomerate, striking 326°, and dipping at 75° to the south-west. The strike and dip of the rocks exposed in the neighbourhood are very variable, and much affected by faulting. A careful inspection of the outcrops on the steep slope above the road shows that an unconformity may possibly exist at a higher horizon than the coal, which in that case will be Eocene, and not Miocene. Though this supposition is supported to some extent by the composition of the coal and by other data obtained from the examination of the neighbouring area—a difficult one to decipher—yet the writers, regarding the opposing evidence as somewhat stronger, have not been able to give it acceptance.

(4.) *Blackwater Valley.*—In the upper watershed of Nada Creek, an eastern branch of the Blackwater River,† brown coal outcrops in a number of places. The first exposure seen on ascending the creek is on the western bank, at a point 750 ft. above sea-level, about two miles or somewhat more from its mouth. Here 22 in. of clean-looking and hard though somewhat dull-lustred coal, underlain by shaly mudstone, and overlain by fine conglomerate, is exposed in a cliff-face 30 ft. above the stream. Analysis No. 8 on page 173 represents a sample broken from the outcrop.

Between 25 and 30 chains farther up the creek a series of coal-outcrops is seen to begin. The observed heights above sea-level are from 765 ft. to 800 ft., and the coal, now on one side of the stream, now on the other, is on the average 10 ft. to 15 ft. in thickness It is clean, in places somewhat friable, but elsewhere hard, of varying but generally moderately bright lustre, and of the composition shown by analysis No. 9 on page 173. The clearest section is as follows: 20 ft. of sandstone, underlain by 8 ft. coal, 3 ft. shale, and 4 ft. coal, with floor not seen. The strike and dip of the coal-bearing strata in this locality are irregular. The observations made are: Strikes, 311° and 261°; dips, 10° to the south-west and 5° to the northward respectively.

A quarter of a mile or more above Zulu Creek junction coal again appears on the western bank of Nada Creek. The outcrop is about 840 ft. above sea-level, and shows a considerable thickness of clean coal resting on sandstone.

A short distance up Zulu Creek from its mouth thick but crushed coal is visible near the left bank at a height of 830 ft. Fine conglomerate and grit, striking 239° and dipping at 40° to the north, outcrop on the right bank. A fault, probably striking with the strata, is evidently here present. Analysis No. 10 on page 173 shows the composition of the coal.

In a rill joining Lily Creek, a branch of Nada Creek, from the south-east a small coal-seam enclosed in shaly rock outcrops at a point not determined by survey, but about half a mile east of north from the 1 ft. 10 in. outcrop in Nada Creek. Towards the head of this rill, at a height of 930 ft., large pieces of coal with a thickness of 2 ft. to 3 ft. occur in the bed, but no outcrop is visible, probably owing to concealment by the huge blocks of limestone and other rocks that more than fill the stream-channel in this locality.

* "Report on the Geology of the South-west Part of Nelson and the Northern Part of Westland." Mines Report, C.-13, 1896, p. 26. Second edition, 1897, p. 60.

† This is not the Blackwater River south of Reefton, but a stream entering the Buller about half-way between Westport and Inangahua Junction.

(5.) *Pensini Creek Watershed.*—Coal has been reported as occurring near Pensini Creek about two miles above its junction with the Buller. Quite probably the statement is correct, but, if so, the coal is involved in a considerable fault that crosses the stream in this locality. Some miles farther up-stream, two or three chains south of the point where the rough trail called the "Buller County Council Prospecting Track" crosses the creek, and immediately below a 30 ft. waterfall, brown coal outcrops on the eastern side in a little rill valley. The seam is over 6 ft. thick, with a sandstone roof passing into a shaly rock, and a gritty sandstone floor. These beds have a slight southerly dip. The upper part of the seam is friable, the lower hard and stony-looking. Small pieces of resin occur somewhat plentifully in the coal. Two or three chains down-stream a seam of clean, fairly hard and bright coal, 8 ft. or more in thickness, outcrops at an approximate height of 990 ft. above sea-level on the right or western bank of the stream.

The bed of the meandering branch of Pensini Creek named "Slug Creek," at the point where it is crossed by the trail mentioned above, exhibits numerous pieces of loose somewhat dull-looking coal. Ten chains above the crossing, at approximately 985 ft. above sea-level, a coal-seam over 6 ft. thick outcrops on both banks and in the stream-channel. The roof is sandstone, and the floor dark carbonaceous sandstone, underlain by light-coloured sandstone. These beds strike nearly north and south, and have a westerly dip of 12° to 15°. A few chains farther up-stream the coal, though hard and clean, as seen on the south side of a meander, is only 4½ ft. thick. Roof and floor are sandstone, dipping gently to the north-west. On the north side of the meander, 15 chains in a straight line from the foot-track crossing, a foot of coal is visible at water-level, whilst a chain farther up a small impure upper seam outcrops on the stream-bank. The enclosing rocks are sandstone, grit, and fine conglomerate. Thirty-two chains north from the track crossing at a point about 1,030 ft. above sea-level, 4 ft. to 5 ft. of not very hard coal, dipping westerly, is seen near water-level.

Seven analyses of coal from Pensini and Slug creeks were made, with the following results :—

—	(1.)	(2.)	(3.)	(4.)	(5.)	(5.)	(7.)
Fixed carbon ..	37·95	40·81	38·37	44·16	40·29	38·08	41·75
Volatile hydrocarbons ..	44·48	39·62	45·05	44·26	44·90	42·21	43·77
Water	14·07	15·57	8·72	10·22	9·56	10·97	11·01
Ash	3·50	4·00	7·86	1·36	5·25	8·74	3·47
Totals	100·00	100·00	100·00	100·00	100·00	100·00	100·00
Total sulphur per cent. ..	2·72	3·01	3·33	4·18	3·50	5·24	2·75
Calories per gram ..	6,077	5,231	6,108	6,235	6,188	5,708	6,038
B.t.u. per pound ..	10,398	9,416	10,994	11,223	11,138	10,274	10,868
Evaporative power per pound in pounds of water at 212° F.	11·34	9·76	11·39	11·63	11·55	10·65	11·26

No. 1 frits but does not cake ; 2 is non-caking ; 3, 4, 6, and 7 form loose cokes ; 5 forms a fairly compact coke. The ash of No. 1 is dark-brown.

(1.) Loose coal from bed of Slug Creek at track-crossing.
(2.) Upper part of seam near Pensini Creek waterfall.
(3.) Lower part of seam near Pensini Creek waterfall.
(4.) From 8 ft. seam, west bank of Pensini Creek.
(5.) From outcrop, about 10 chains above track crossing, Slug Creek.
(6.) From 4½ ft. outcrop, about 14 chains above track crossing, Slug Creek.
(7.) From 4 ft. to 5 ft. outcrop, about 32 chains above track crossing, Slug Creek.

The brown coal of Pensini Creek valley on the whole is of good quality and very suitable for household use. It resists weathering very fairly, and therefore could be transported without trouble arising from its disintegration. The locality, however, is remote and difficult of access, so that there is no probability of the deposits being utilized in the near future.

(6.) *Blue Duck Creek.*—In Blue Duck Creek, a tributary of the Mackley, two outcrops of coal were noted by Mr. H. S. Whitehorn, Assistant Topographer. The lower of these is just outside the southern boundary of Orikaka Survey District, and approximately 90 chains or 1⅛ miles* south of east from the mouth of the stream. Here 3 ft. of hard bright coal, underlain by 3 ft. of mudstone or shale, and this again by 1 ft. of coal, is visible. The beds strike 356°, and dip 33° to the west, apparently under coarse grit or fine conglomerate. Analyses 12 and 13 on page 173 show the composition of the upper 3 ft. seam. A mile* to the north of east from the locality just mentioned a seam of hard and bright coal, probably not more than 2 ft. thick, outcrops in the stream-bed. It has a strike of 221° and a dip of 55° to the south-east. Its composition is shown by analysis No. 14 on page 173.

From the analyses it will be seen that the Blue Duck Creek coal is almost bituminous in character, and is therefore similar to the highly altered Miocene coals near Three-channel Flat and Reefton.

"DOUGHBOYS."

"Doughboys" are masses of soft material, found chiefly in the Seddonville coal. They have also been observed, though of smaller size, in the Liverpool State Colliery, Greymouth. The average "doughboy" is a lenticular body from 1 ft. to 2 ft. in maximum thickness, with a length or diameter of 8 ft. to 20 ft., and in some cases throws off more or less irregular branches or arms. The component material is almost without coherence, and so soft that a pointed stick can be easily pushed several feet into it. When dug out it falls into a dark-brown powder, of low specific gravity, that balls with the pressure of the hand like damp bone-ash.

"Doughboys" are highly objectionable because they form a large amount of fine dust that cannot be effectually separated from the coal, and where, as is usually the case, they are associated with friable coal, the evil is intensified. Analysis shows that they contain a surprising amount of combustible matter, and, in fact, differ but little from ordinary coal in proximate composition. Hence they are thought to represent drifted trees that have not been changed to the usual coaly substance. Their composition is shown by the following analyses:—

	(1.)	(2.)	(3.)
Fixed carbon	53·30	52·78	45·89
Volatile hydrocarbons	36·00	39·87	40·73
Water	8·80	5·49	6·32
Ash	1·90	1·86	7·06
	100·00	100·00	100·00
Total sulphur per cent.	..	4·52	3·51

(1.) Seddonville State Colliery. Dom. Lab. Rep. No. 38, 1905, p. 5.
(2 and 3.) Seddonville State Colliery. Collected by Geological Survey in October, 1913. These samples are noted by the analyst as forming firm cokes.

* In following the stream these distances would be quite doubled.

RESIN.

The occurrence of visible resin in the bituminous coals of Eocene age at Seddonville, Mokihinui Mine, and Denniston has already been mentioned. In the Seddonville State Colliery the resin is in rounded or irregular lumps, the latter of such a shape that they cannot have been transported as such by water, and therefore it is supposed that they are derived from floated trees. All the brown coals and lignite contain more or less resin, and this substance is especially abundant at Charleston, where it occurs both as lumps and as thin layers in the lignite. Of the following ultimate analyses, (1) represents resin from Sweeney's pit, Charleston, (2) is an analysis of fossil resin from Drury coal, Auckland, made by Richard Maly, and quoted by Hochstetter*, and (3) is an analysis of "retinite" from the Dunstan, quoted by Liversidge† :—

	(1.)	(2.)	(3.)
Hydrogen	7·97	10·58	11·512
Carbon	67·57	76·53	75·979
Nitrogen	0·42	..	..
Oxygen	20·08	(12·70)	12·306
Sulphur	3·04	..	..
Ash	0·92	0·19	0·203
	100·00	100·00	100·000

The Charleston resin differs from most fossil resins in having lower percentages of carbon and hydrogen, together with higher percentages of oxygen and sulphur. In these respects it follows the coal with which it is associated (see analyses on page 175).

"ROLLS."

The term "roll" as used by coal-miners may mean either an undulation in the coal-bearing strata, or a temporary thinning of the coal-seam produced either by a rising of the floor or by a depression of the roof. In this latter sense the term "squeeze" is employed in some districts. Diagrams illustrating rolls are given in Bulletin No. 13 (Greymouth), pages 127 and 128.

In the Westport district the ordinary type of "roll" is a thinning of the coal-seam, which is almost invariably accompanied by slight movement of the enclosing strata, and thus partakes of the nature of the undulatory or stratigraphical roll as well. Very commonly a small fault accompanies the roll, or the disturbance is in one place a mere undulation, and in another a fault. The Millerton and Mangatini faults illustrate this phenomenon on a large scale (see Chapter IV and Fig. 1), but in these cases thinning of the involved coal, so far as the writers know, has not been shown to exist. References to rolls in the Seddonville mines will be found earlier in this chapter.

A matter of importance is the fact that a roll accompanied by arching or doming of the coal-measures, however slight, may give rise to an accumulation of firedamp or other gas at the summit both in the coal itself, and more especially in the stratum above.

"SWALLOWS."

A "swallow" is a small local depression or basin in coal-bearing strata, and thus may be looked upon as a variety of "roll." A structure of this kind is exhibited by the Mangatini seam immediately south of Mine Creek township. The thickness and quality of the coal are not affected.

* "New Zealand," 1867, p. 79.

† Notes on some of the New Zealand Minerals belonging to the Otago Museum, Dunedin." Trans., vol. x, 1878, p. 490. See also Rep. N.Z. Exhibition, 1868, p. 438 (reference given by Hector in footnote).

COAL IN GROUND.

I. *Bituminous Coal.*

Former Estimates.

In 1862 James Burnett,* on what was supposed to be a conservative basis, estimated that 72,600,000 tons of coal could be extracted from the upper Waimangaroa, Coalbrookdale, and Mount Rochfort districts. This, however, was unfortunately a considerable overestimate for the area to which Burnett referred.

In a report dated 1st March, 1875, and published in 1877†, Cox made the following rough estimate of the quantity of coal in the field:—

	Tons.
Waimangaroa basin	32,000,000
Ngakawau basin—high level	36,000,000
,, middle level	56,000,000
,, low level	16,000,000
Total	140,000,000

Cox's estimate has been adopted by Park‡.

In 1877 Hector§ published the following important data obtained as a result of Cooper and Denniston's survey of the area extending from the Ngakawau River to Mount Rochfort:—

Locality.	Approximate Extent, in Acres.	Average Thickness, in Feet.	Workable Coal, in Tons.	Remarks by Present Writers.
Area 1	500	13	4,875,000	Coal in ground according to data 9,750,000 tons, or twice workable coal.
Area 2	860	7	4,515,000	Coal in ground, 9,030,000 tons.
Area 3	640	4	1,920,000	Coal in ground, 3,840,000 tons.
Area 4	1,500	17	19,125,000	Coal in ground, 38,250,000 tons.
Area 5	900	23	15,550,000	Coal in ground, 31,050,000 tons. Workable coal presumably intended to be given as half that in ground, *i.e.*, 15,525,000 tons.
Area 7	100	15	1,687,500	Coal in ground, 2,250,000 tons. Possibly area should be 150 acres.
High level A	300	17	3,825,000	Coal in ground, 7,650,000 tons.
High level B	75	17	956,000	Coal in ground, 1,912,500 tons.
High level C	100	14	1,050,000	Coal in ground, 2,100,000 tons.
Low level C	122	12	1,098,000	Coal in ground, 2,196,000 tons.
High level D	300	15	3,375,000	Coal in ground, 6,750,000 tons.
Mid level D	1,105	15	12,431,250	Coal in ground, 24,862,500 tons.
Low level D	455	20	6,825,000	Coal in ground, 13,650,000 tons.
Mid level E	420	14	4,410,000	Coal in ground, 8,820,000 tons.
Southern edge of Waimangaroa Gorge	90	6	450,000	Coal in ground, 810,000 tons. Half this is 405,000 tons.
Mount William ..	180	15	2,025,000	Coal in ground, 4,050,000 tons.
Todea Creek	225	25	4,218,750	Coal in ground, 8,437,500 tons.
Coalbrookdale ..	600	12	5,400,000	Coal in ground, 10,800,000 tons.
High level of Coalbrookdale	770	9	5,197,500	Coal in ground, 10,395,000 tons.
Mount Rochfort ..	200	4	600,000	Coal in ground, 1,200,000 tons.
Lower Waimangaroa ..	1,200	9	6,000,000	Coal in ground, 16,200,000 tons.
Total	10,642	13·4‖	105,534,000¶	Coal in ground, 214,003,500 tons.

* "Report on the Grey Coalfield North of the Buller River." *Nelson Gazette*, vol. x, 1862, No. 21, pp. 73–83.

† "Report on Survey of Buller Coalfield." Rep. G.S. during 1874–76, No. 9, 1877, p. 26.

‡ "On the Extent and Duration of Workable Coal in New Zealand," Trans., vol. xxi, 1889, p. 329; "The Geology of New Zealand," 1910, p. 288.

§ Progress Report in Rep. G.S. during 1876–77, No. 10, 1877, pp. xv–xvi.

‖ Average thickness as calculated by writers from data in table.

¶ In the original this total is printed as 105,034,000 tons.

Comment on Hector's Estimates.

From the table above (which contains several small clerical errors) it is evident that Hector adopted as a basis for the calculation the usual figure of 1,500 tons per acre-foot, and in all cases except the last adopted 2 as a factor of safety: that is, he assumed that approximately half the coal in the ground was workable, or, as the writers suppose, extractable. Though in one or two instances Hector's estimate of workable coal may be under the mark, on the whole in the light of later knowledge it requires considerable discounting, partly because the area of workable coal is less than supposed by him, and partly because the average thickness of the seams is probably not so great as the estimate. Hector himself was well aware of the dubious elements that enter into all New Zealand estimates of coal, for on one occasion he said, "Nearly all our coals, especially those on the West Coast, have been formed in deposits like the Canterbury Plains. There are great quantities of conglomerates, and it is quite obvious that a fluviatile formation of that kind must be very liable to run out. . . . They are not seams that can be depended upon for steadiness, such as we are accustomed to find in the Carboniferous rocks of the Old Country."*

Areas 1, 2, and 3 (see map at end of Denniston's report) are situated between the Ngakawau River and the Millerton fault. Thick coal outcrops near the mouth of Mine Creek and on the top of Crane Cliff, but elsewhere only somewhat thin coal is known. The proved coal is small in amount, and of little value under present New Zealand conditions.

Areas 4, 5, and high level A together form a triangular area with its base on the Millerton fault and its apex near the head of the Waimangaroa River. The estimates of area may be considered accurate, but those of thickness are not on a conservative basis.

Area 7, situated some distance east of areas 4 and 5, is that lately attacked by the Westport-Stockton Coal Company. This area is much underestimated, for considerable portions of the supposed barren area 8 and of low level A (between Plover Creek and St. Patrick Stream) must be added.

In high level B (Mount Frederick) the area of workable coal is underestimated, but the thickness is probably overestimated for the area given, and is certainly so for the full area.

High level C, south of Mount Frederick and west of Deep Creek, is shown as a blank on Cooper and Denniston's maps. Actually it is a patchy piece of ground, which may contain the estimated amount of coal.

So far as shown by outcrops the coal of low level C near the right-angled bend of the Upper Waimangaroa is thin, but may extend southward over a larger area, and there be thicker (or it may not).

The coal of high level D, formerly worked to some extent by the Koranui Company, is not so thick as estimated; and the area may also be overestimated. Middle and low level D together form a large area extending southward from Webb Creek on both sides of the Waimangaroa. So far as the evidence of outcrops goes, the coal-bearing area in middle level D is very much overestimated, and the same statement applies to the estimated average thickness. Boring, however, may ultimately prove the area to be equal to Hector's (Denniston's) estimate.

The estimated area of mid level E (Burnett's Face to Kiwi Compressor) is perhaps under the mark.

The figures given for the small block on the south side of Waimangaroa Gorge may be considered approximately correct. This area was worked as the "Banbury Mine."

The area of workable coal given for Mount William agrees with the writers' estimate, but it is to be feared that, owing to dirt bands and other defects, the extractable coal is less than Hector's estimate.

* Report of Coal-mines Commission, C.-4, 1901, p. 324.

The Todea (Cascade) Creek block does not contain nearly so much coal as the estimate. Both area and thickness are exaggerated.

The area and thickness of coal given for Coalbrookdale may be accepted, but there is reason for believing that the "high level" extending into the headwaters of the Whareatea will not be so productive as estimated.

The Mount Rochfort area is a doubtful one, and probably does not contain coal workable under present condtions.

The extent of the proved coal in the lower Waimangaroa area is very small indeed, and the estimate given is at best one of possible coal.

Estimates of Present Survey.

In 1911, before much field-work had been done, one of the present writers estimated that the total amount of proved bituminous coal in the Buller-Mokihinui district was 221,000,000 tons, so that, including mined coal, the quantity originally present was 231,000,000 tons.* Hector's 214,000,000 tons was accepted as the basis for this estimate, which was supposed to include all coal contained in seams over 1 ft. thick.

Under present New Zealand conditions coal-seams in small blocks or under 4 ft. in average thickness, especially if faulted or otherwise irregular, cannot be profitably mined, and therefore may be discarded in making any estimate of workable coal. The reader, however, is not to suppose that the estimates presently to be given represent workable or extractable coal unless this is specifically stated.

Notwithstanding the numerous outcrops of bituminous coal between Mount Rochfort and the Mokihinui River, the area and thickness of workable coal cannot be exactly defined, partly on account of the irregular boundaries, but much more on account of the lenticular nature of the coal-seams, and the manner in which coal is replaced by shale in some localities. In the following table the areas may be regarded as approximately correct, and the estimates of average thickness as conservative—that is, they are probably somewhat under the mark. The probable drift origin of the coal-deposits, their lenticular nature, and the occurrence of dirt bands in the coal of several districts, are all facts that compel caution in estimating the average thickness and area. The coal already extracted is included in the tonnages.

APPROXIMATE ESTIMATE OF PROVED AND HIGHLY PROBABLE COAL.

Locality.	Coal-bearing Area, in Acres.	Average Thickness of Coal, in Feet.	Proved or Highly Probable Coal, in Tons.	Remarks.
Ridge south-west of lower Chasm Creek	18	5	135,000	Not workable at a profit.
Cardiff Mine north of Chasm Creek	84	8	1,008,000	Area partly worked and abandoned. Coal on fire.
Seddonville State Colliery, north of Chasm Creek	96	10	1,440,000	Area worked and abandoned.
Mokihinui Mines	136	6	1,224,000	Area partly worked and then abandoned. Some coal destroyed by fire.
South of Chasm Creek in Mokihinui Survey District	216	6	1,944,000	Small areas worked. Coal proved by boring and outcrops.
Charming Creek valley in Ngakawau Survey District	{ 30 { 130	15 7	} 2,040,000	Proved by boring.
Outlying areas	20	4	120,000	Partly worked and abandoned.
Totals for Seddonville-Mokihinui district	730	7·22	7,911,000	Possible area and tonnage considerably greater.

* P. G. Morgan: "The Coal Resources of New Zealand" in "The Coal Resources of the World," Toronto, 1913, vol. i, p. 81. See also Proc. Aust. Inst. of M.E., No. 9 (New Series), 1913, p. 19.

APPROXIMATE ESTIMATE OF PROVED AND HIGHLY PROBABLE COAL—*continued.*

Locality.	Coal-bearing Area, in Acres.	Average Thickness of Coal, in Feet.	Proved or Highly Probable Coal, in Tons.	Remarks.
Mangatini seam, mainly in Westport and Westport-Stockton leases	2,200	14	46,200,000	Areas being actively worked on a large scale.
	480	10	7,200,000	
Matipo seam, mainly in Westport-Stockton lease	300	10	4,500,000	Now being worked.
	680	6	6,120,000	Probable rather than proved.
Outlying areas	100	8	1,200,000	Partly worked (Albion, &c.).
Totals for Mangatini and adjoining districts	3,760	11·57	65,220,000	Contains more than half the proved coal. Some probable coal may be added to estimate.
Mount Frederick outlier ..	140	8	1,680,000	Good coal.
Mount William outlier	180	8	2,160,000	Amount may be increased by including dirty coal.
Waimangaroa Valley, from Webb Creek to Kiwi Compressor (mainly in "Cook's" or "Westenra's" lease)	800	8	9,600,000	Much of this coal is probable rather than proved.
Kiwi compressor to Burnett's Face	480	9	6,480,000	Conservative estimate. Coal in split not included, no data being available.
Coalbrookdale, Upper Cascade Creek, and Whareatea	1,080	10	16,200,000	Coal in split not included. This and last area are being actively worked on a large scale.
Upper Deep Creek watershed ..	100	10	1,500,000	Coal probable rather than proved.
Old Koranui lease, &c. ..	80	6	720,000	Partly worked and abandoned.
South of Waimangaroa Gorge (Banbury Mine)	96	5	720,000	Area worked.
Outlying areas	100	8	1,200,000	Partly worked and abandoned.
Totals for Waimangaroa Valley, &c.	2,736	8·87	36,420,000	Some coal in splits and some probable coal may be added.
Totals	7,546	10·02	113,391,000	
Coal in splits, minor workable seams, &c.	..	..	10,000,000	Rough estimate or guess.
Grand total, excluding Blackburn area	7,546	10·90	123,391,000	A moderate amount of probable coal may be added.
Blackburn district	200	10	3,000,000	Rough estimate. The area is practically unexplored. Boring may prove much additional coal.

To the total of approximately 123,000,000 tons of proved coal may be added the coal in outlying patches east of the Mount William Range, that in various thin seams, such as the upper seam in the Seddonville district, and that contained in the margins of the larger seams where these thin to less than 4 ft.; but none of this coal can be regarded as workable at the present time. Owing to the average thickness of the main seams having been estimated on a conservative basis, believed to be on the safe side, 5 to 10 per cent. may be added to most of the tabulated quantities as probable. Other probable coal may be proved by boring in the Mokihinui district, in the neighbourhood of Kiwi fault, on the flats near Waimangaroa, in the Blackburn district, and elsewhere. It is, however, not feasible to make any estimates of probable or possible coal in these localities.

Extractable Bituminous Coal.

Where the seam worked is not too thick and the coal is of good quality, the percentage of extraction is fairly high. Data for the larger mines of the Westport district are not yet available, owing to the unknown amount of coal standing in pillars; but it may be assumed that the extraction will not exceed 50 per cent., for much coal cannot be won where the seam is thick, a large proportion of the "soft" or friable coal is left unworked, and some coal is lost through mine-fires. Some of the smaller mines, especially in the Mokihinui district, have given very poor results. Thus the Seddonville State Colliery appears to have extracted not more than one-third of the coal in the area commanded by mine-development, and the Cardiff Mine less than one-fourth. The Mokihinui Mine has an even poorer record.

Since the best portions of the Buller coalfield are now being worked on a large scale, and therefore being exhausted at a rapid rate, it follows that the next generation of miners will have to work the less-accessible and generally poorer portions of the field. They will, therefore, have great difficulty in obtaining a sufficient return for their labour and capital; and under such conditions there will be little inducement to work the mines so as to obtain a high percentage of coal-extraction. Hence, the writers conclude that until the market-price of the coal materially increases not more than 60,000,000 tons out of the 123,000,000 proved tons* can be considered workable. But of this 60,000,000 tons, 13,000,000 tons had been mined at the end of 1914, and hence the certainly extractable or workable coal reduced to 47,000,000 tons or less. On this basis the life of the bituminous coalfield becomes short indeed compared with that of coalfields in many other parts of the world. On the other hand, further supplies of coal will be proved in the Blackburn district and perhaps elsewhere; but it is the duty of the writers to point out that there is little warrant for supposing that the future holds more than modest possibilities. That unpleasant thing to the consumer, an increase in the selling-price of the coal, appears inevitable, but this may have the good effect of enabling a greater proportion of the coal to be mined.

II. *Brown Coal and Lignite.*

The brown coal or lignite of the Charleston district is shown by outcrops to exist over areas totalling several hundred acres, where it has a thickness of from 4 ft. to over 20 ft. Thus there are probably some millions of tons of coal in the neighbourhood of Charleston alone. Though lignite almost certainly has a considerable development under the limestone to the east, and also northward towards Tauranga Bay, no further estimate of quantity can well be made. In the same way it would be idle to speculate as to the amount of brown coal in those portions of the Inangahua coalfield extending into the south-east part of Orikaka Survey District and the eastern part of Ohika Survey District. Probably the quantity of coal in each locality is considerable, but the difficulties of access and transport will prevent any attempt to work the coal for many years to come.

COAL-PROSPECTING—BORES, ETC.

From time to time numerous bores have been drilled in various parts of the Westport district in search of coal. The first of these was an unsuccessful bore mentioned by Hector in 1867 as drilled "at the western limit of the plateau."† Between Millerton and Darlington several bores were drilled many years ago, two or three of which are reported to have passed through coal from 3 ft. to 5 ft. thick. A map of the Westport-Cardiff Colliery lease (Seddonville), published in 1901, shows the position of twelve boreholes. Six of these in the "Cave area" penetrated from 3 ft. to 17½ ft. of coal, and the average thickness shown was nearly 12 ft. In later

* The Blackburn coal, being as yet practically unproved, is excluded from this discussion.
† "Abstract Report on the Progress of the Geological Survey of New Zealand during 1866–67," 1867, p. 11. See also G.S. Rep. No. 4, 1868, p. 23.

years the Mines Department made additional borings in the "Cavĕ area" and also near Seddonville. Six holes were also drilled by hand on the south side of Chasm Creek near the Bridge section of the State colliery. One of these passed through 7½ ft. of coal, but the others, according to the logs, reached the basal granite without finding coal. During the years 1910–12 no less than sixteen borings were made in Charming Creek valley and the area immediately to the north. Of these bores Nos. 1, 2, 5, and 7 were drilled by hand, the remainder by diamond drill. The results obtained are summarized on pages 148–49.

According to Hector a bore at Mokihinui Mine (Coal Creek) in 1887 intersected the following beds below the main seam: Clay, 1½ ft.; coal, 3 ft.; grit, 18 ft.; coal, 7½ ft.; clay; thus showing the presence of a second workable seam.*

The borings made on the Westport-Stockton lease during the past few years are briefly described on page 160. The two bores shown on the maps in West Creek valley near the Buller were probably drilled by the Aorangi Consolidated Company, which at one time held a lease of 1,198 acres in that locality.†

The advisability of boring the Westport flats for coal has been mooted for nearly half a century. A few years ago the Westport Coal Company drilled two holes on the western side of the railway between Sergeant's Hill and Fairdown. The bore near Fairdown was begun in July, 1907, and had reached a depth of 1,742 ft. when the rods broke and drilling was abandoned. That near Fairdown, begun in August, 1908, was drilled to a depth of 2,500 ft. when the rods once more broke and work was discontinued.‡ After passing through the surface gravels these bores entered Upper Oamaru claystone and sandstone, with occasional calcareous bands. So far as can be learnt, neither bore passed out of the Miocene rocks, and therefore it is evident that in this locality the bituminous coal-measures are very deep.

Some years ago two shallow bores were drilled and a small shaft was sunk by Mr. F. F. Munro near Tauranga Bay in Miocene strata. These penetrated the lignite that outcrops not far away, but otherwise yielded no information of moment.

In 1912 the Westport Harbour Board drilled a hole near Wilson's Lead Road (Addison's Flat) to a depth of 825 ft. in Upper Oamaru strata. Owing to difficulties caused by calcareous concretions (reported as "boulders") and caving ground, the bore was then abandoned. The site was well chosen for the object in view, and had the bore been carried to a depth of 2,500 ft. or 3,000 ft. some valuable information would probably have been obtained. From a section (with notes) made by the driller in charge (Mr. W. Carter), and kindly lent by the Westport Harbour Board, the following particulars have been obtained: At 14 ft. alluvial wash (Pleistocene marine gravel and sand) ends; at 70 ft., 1 ft. 3 in. hard band; at 150–170 ft., a series of hard bands; at 195 ft. and 222 ft. are 1 ft. 3 in. and 1 ft. 6 in. "felstone" bands; at 287 ft., 6 in. deposit of shells; at 304 ft., 6 in. of lignite; at 331 ft., 6 ft. "felstone band"; at 452 ft., 600 ft., 625 ft., 668 ft. 4 in., 690 ft., 750 ft., and 810 ft., "boulders"; at 590 ft., crushing took place; at 610 ft., flow of water and sand; at 690–750 ft., swelling ground; at 750–800 ft., moving boulders and débris, with strong flow of water.

The hard " elstone" bands of this record are presumably concretionary calcareous bands, similar in nature to the "boulders." The bore was cased with 6 in. lining-tubes to 150 ft., and with 4 in. collar-jointed tubes to 612 ft. All the casing was withdrawn when the bore was abandoned.

It is evident that this bore was not started with a diameter large enough to enable a deep hole to be drilled.

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* "On the Mokihinui Coalfield." Rep. G.S. during 1886–87, No. 18, 1887, p. 160.
† See map of Buller coalfield in Mines Report, 1907, opposite p. 12 of C.–3A.
‡ Information supplied by Westport Coal Company.

Towards the end of 1913 a second bore with an initial diameter of 8 in. was started by the Harbour Board near the coast at a point somewhat over a mile north-west of Waimangaroa Junction Railway-station. This locality had been recommended by one o the writers as suitable for a trial bore.* Difficulty was experienced in driving the casing through the loose sand and fine shingle that formed the surface strata. At a depth o somewhat over 80 ft. trouble was caused by a boulder or boulders, probably resting on the Miocene bedrock. At this stage the foundation for the plant was ound to be inefficient, and another bore with a diameter of 10 in. was started about 200 yards nearer the railway-station. Here loose drift was penetrated for 60 ft., when a large boulder which stopped the 10 in. casing was encountered. The bore was continued with 8 in. casing, but this being deflected by the boulder at 60 ft., and another boulder being strruck at 80 ft., the bore was abandoned.

In 1914, according to a newspaper report, the Harbour Board began drilling near Tauranga Bay, but no further record has been seen by the writers. The locality is not one that can be recommended.

RECOMMENDATIONS *re* PROSPECTING.

Owing to the numerous outcrops of coal-bearing strata the greater part of the Buller coalfield has been prospected by surface explorations, such as trenching, the driving of short adits, &c. Owing to the prevalence of splits from the main seams, and the rapidity with which a thin seam occasionally thickens, various apparently barren areas or strata may deserve to be tested by boring before being finally condemned. Among such localities may be mentioned the ground on both sides of Kiwi fault, near "Cook's" or "Westenra's" lease. Though much of the area in the eastern part of the Westport-Stockton lease lately found to be coal-bearing was mapped by Denniston as barren, yet outcrops indicate its coal-bearing character (see pages 157–61), and therefore this ground does not fall into the above category. Denniston evidently was misled through failing to note the remarkable split of the Mangatini and Matipo seams.

Among the areas that require boring are "Cook's lease," together with part of the ground to the north-west and north of Seddonville Flat, the country east of Mokihinui Mine (Maori reserve, &c.), and in particular the Blackburn district. Notwithstanding its remoteness and the difficulty of access, the Blackburn area may be recommended as offering the best chances of a new coalfield in the Westport district.

Westport Flats.—One of the writers† has already reported on the question of boring the Westport flats, and much of what was then written need not be repeated here. Undoubtedly in the somewhat near future the depletion of the known coal resources will compel the systematic boring of this conveniently situated area in order to ascertain its coal-contents.

It is necessary to state that, except on the inner margin of the coastal plain in the Lower Buller or Kongahu fault-zone, the coal will everywhere be deep, and probably in few places much less than 3,000 ft. below the surface. There is, however, one geological factor that tends to reduce the distance to be drilled, and that is the unconformity between the Eocene coal-measures and the Miocene rocks that form their cover throughout the coastal region. This may lessen the depth to coal in two ways —first, through pre-Miocene erosion of the coal-measures; and, second, through overlap of the Miocene rocks upon the Eocene strata, such as probably has taken place at

* P. G. Morgan: "The Coal Possibilities of the Westport Flats." N.Z.G.S. Seventh Ann. Rep., C.-2, 1913, pp. 124–26.
† P. G. Morgan, *op. cit.*

Waimangaroa, and again near Mokihinui, as seen in the Brewery Creek section. On the other hand, the pre-Miocene erosion may have gone so far as to remove the coal-seams. Whether, for example, this has occurred at Cape Foulwind, or whether the Eocene coal-measures were never deposited in that locality, cannot be determined with our present knowledge, but in either case boring in the immediate neighbourhood will be useless unless an unusual combination of favourable conditions happens to exist.

Coal may reasonably be expected to exist beneath the Waimangaroa flats, and will probably extend southward as far as or beyond Addison's, and northward beyond Birchfield. In the last-named locality the conditions for bituminous coal at moderate depth are perhaps more favourable than elsewhere. Those interested, however, must be warned not to expect too much from any locality. The lenticularity of all New Zealand coal-seams, the prevalence of faults and other troubles, the known absence of Eocene strata from the Cape Foulwind and Charleston districts, and the great depth to which boreholes must be carried, all combine to render the exploration of the Westport flats a difficult and expensive operation, not to be lightly or casually undertaken. It need hardly be said that adequate capital, first-class boring plants, and experienced drillers must all be obtained before the search for coal can be undertaken with any real hope of success. In the opinion of the writers the best sites for trial bores are towards the coast-line near Birchfield, Waimangaroa, and Fairdown, and about half-way between Cape Foulwind and the bituminous coal-outcrop on Moran's water-race. In a report written during 1900 McKay* apparently discourages a proposal to bore near Waimangaroa, on the ground that the coal will be excessively deep; but this objection probably applies to the whole coastal plain. He recommends a bore at or near the mouth of the Ngakawau, and in a later report† dated 23rd August, 1912, favours bores near Cape Foulwind also. Though coal may well be found at moderate depth near the Ngakawau River mouth, yet the rocks here are involved in the Lower Buller fault, and consequently the same objection applies as at Waimangaroa Village and other localities near the foot of the ranges—that is, any coal found will be broken and standing at high angles. As already pointed out, bores near Cape Foulwind are not likely to be successful, since there the bituminous coal-measures either never existed or have been removed by erosion. Only by the greatest good fortune will the result justify any boring done within two miles of the coast in this part of the district. Similar conditions, it may be added, exist farther south at Charleston and Brighton.

Brown Coal and Lignite Areas.—Probably, as already stated, and as may be inferred from the general geology of the district, lignitic coal, similar to that of the Charleston and Tauranga Bay areas, has considerable development beneath other parts of the coastal region, and can therefore be proved by boring. Owing to the inferior quality of the known Miocene coal near the coast, expense in this direction is not warranted at the present time. In the future the lignite will doubtless be followed from the outcrops into deeper ground, whilst the boring of the Westport flats for bituminous coal will probably afford important data with respect to lignite also.

The brown coals of the Blackwater Valley, Pensini Creek, &c., are of much better quality than the coastal lignite. They belong to the important Inangahua field, which in the not far distant future will probably be extensively developed. At the present time the portions of this coalfield within the Buller-Mokihinui Subdivision do not call for prospecting.

* "Report on the Prospect of Coal at Waimangaroa Railway-station, Westport." C.-10, 1901, pp. 2, 6-7.

† Printed by the Westport Harbour Board as a leaflet.

Water-resources.

Thanks to the abundant rainfall, there is no scarcity of running water in the Buller-Mokihinui district. Some of the upland streams, however, notably Mine Creek, are polluted by acid water from the mines or from areas where the coal is on fire, and by drainage from the mining townships. For this reason Millerton, Mine Creek, and Burnett's Face in dry weather suffer from a lack of water suitable for household purposes. Denniston, being almost on the top of a hill, is also without a permanent water-supply. Owing to the rapid run-off from the bare upland surfaces, the small streams and rills soon lose most or all of their water in fine weather. Thus not only at Denniston, but also at Coalbrookdale, Millerton, and elsewhere, dams are necessary in order to conserve water for steam and other industrial purposes.

An abundant supply of water is necessary in connection with alluvial gold-mining, and hence the numerous dams mentioned on an earlier page as constructed in the coastal region near Westport, Addison's Flat, Charleston, &c. Large and permanent supplies of water under a sufficient head for hydraulic sluicing can be obtained, but only at a cost that in most cases seems prohibitive.

Notwithstanding its mountainous character, the subdivision does not present more than moderate water-power possibilities. There are, however, many small streams that could each be made to furnish a limited amount of energy, if there were any demand for such. Formerly water-wheels were used to a considerable extent in the cement-batteries at Bradshaw's, Addison's, and Charleston, and one or two of these are still in commission.

Among the medium-sized streams, the Ngakawau and the Waimangaroa offer some possibilities in close proximity to mining districts and centres of population. The former stream, in passing through the three miles and a half of gorge between St. Andrew Stream and Charming Creek, falls over 500 ft., and since the ordinary dry weather flow at the upper end of the gorge is fully 100 heads, several thousand horse-power could be developed. In a distance of three miles below its junction with Burnett Creek, the Waimangaroa falls over 800 ft., mainly in the first mile. This stream, however, is normally much smaller than the Ngakawau, and has a low minimum flow, owing to much of its watershed being unforested upland, with little soil and scanty vegetation. The latter objection applies also to the Whareatea River, Mangatini Creek, Mine Creek, and other streams draining the bituminous coal district and exhibiting falls at some part of their courses.

If the Westport flats should ever be successfully developed as a coalfield, considerable value will be given to the water-power derivable from the Waimangaroa and Whareatea rivers. Similarly the water-power obtainable at the Ngakawau gorge and from streams draining the Glasgow Range is a potential asset in connection with the development of the Blackburn field.

Summary of Economic Geology.

The auriferous quartz veins of the Westport district are not of great importance. The only locality within the Buller-Mokihinui Subdivision where such veins have been worked is near Waimangaroa, but the Mokihinui and Lyell fields are near its borders.

The auriferous alluvial deposits of Charleston, Addison's, and other districts were at one time famous throughout New Zealand. Though now largely exhausted, they still offer modest possibilities to the miner. The occurrence of platinum, stream-tin, monazite, and other substances in the alluvia of the subdivision is of scientific rather than economic interest.

Various other minerals, such as barite, mica, potash-feldspar, and iron-ores are not known to occur in commercially workable deposits, but in some cases there are doubtless possibilities that cannot be foreseen at the present time.

The building-stones, limestones, and clays of the subdivision will become of great value at some future time. The manufacture of cement from the limestone and clay near Cape Foulwind is apparently a feasible proposition.

The subdivision's great mineral asset is its magnificent bituminous coal, which for a number of years has been actively mined on a large scale. The total amount of proved coal originally in the ground is estimated at 123,000,000 tons, of which about half, or 60,000,000 tons may be considered extractable under present conditions, but of this 13,000,000 tons has already been mined, leaving only 47,000,000 tons as minable. To the proved coal may be added a considerable amount of probable coal, and coal that may possibly be proved by boring to exist under the Westport flats and elsewhere. The whole situation, however, calls for the serious consideration of all interested in seeing that the far from inexhaustible coal-resources of New Zealand are properly husbanded and utilized to the best advantage.

In addition to the bituminous coal there are considerable quantities of brown and lignitic coal. The full extent of the areas containing these fuels is not known at the present time.

APPENDICES.

APPENDIX I.

LIST OF MINERAL SUBSTANCES FOUND IN THE BULLER-MOKIHINUI SUBDIVISION.

Actinolite: Found chiefly in aggregates resembling "eyes" in some schists and hornfels in the Mokihinui Valley. Occasionally present as a derivative from pleochroic green hornblende in some of the intermediate igneous rocks. (See page 103.)

Alum: In the "Handbook of New Zealand Mines," 1887, p. 221, alum-shale is recorded at Mokihinui. A little alum has been formed with the aid of steam and other gases emitted from the burning coal of the old Mokihinui Mine. Incrustations containing alum occur under an overhanging cliff near Kiwi Compressor, east of Burnett's Face. A sample taken in 1912 contained approximately 8·5 per cent. of potash-alum.

Amphibole: See Hornblende.

Andesine: Common in the intermediate igneous rocks of the district.

Anorthoclase: A cryptoperthitic feldspar present in some granites and quartz-porphyries is probably anorthoclase.

Antimony-ore: See Stibnite.

Apatite: Occurs in small amount in the igneous rocks. In the diorites it is sometimes an important accessory mineral.

Arsenopyrite: A pyritiferous rock containing a little arsenopyrite (arsenical pyrites) was forwarded to the Colonial Laboratory from Mount Rochfort in 1877 (Lab. Rep. No. 13, 1878, p. 24).

Augite: This mineral, partly altered to uralite, is present in a dolerite found in stream-gravels near the new Karamea–Mokihinui Road, and a highly titaniferous variety is the most important constituent of the Blackwater River camptonites. (See Chapter V.)

Barite: Reported to occur at Cascade Creek (Mines Report, 1887, p. 136); found in small veins in coal-measure grits south-east of Millerton, and in quartz-porphyry at Coalbrookdale (see page 123). Dr. Gaze reports a mixture of barium and calcium-sulphates—"dreelite"—from Cascade Creek ("An Introduction to Analytical Pyrology," 1888, pp. 31–32).

Barkevikite (Barkevicite): See Hornblende.

Biotite: A common constituent of the igneous rocks, hornfels, schist, &c.

Bismuth: Sydney Fry (*fide* Kenneth Ross) discovered a fragment of bismuth dotted with gold in gravels (sluice-box concentrates), Waimangaroa district (*Mines Record*, vol. 10, 1906–7, p. 12).

Black sand: See Magnetite, Ilmenite.

Bog-iron ore: See Iron-ochre.

Calcite: The essential constituent of the various limestones, and forms a proportion of the other calcareous rocks. Small veins occur in Kaiata mudstone, gneiss, granite, &c., in several localities.

Cassiterite: Material containing 54 per cent. of tin is reported from the Buller district (Lab. No. 21, 1886, p. 46, and Handbook of N.Z. Mines, 1887, p. 221), but the exact locality is not stated. Stream-tin has been reported from the foot of the Mount William Range, the discovery being attributed to Dr. Gaze and Mr. J. F. Clarke (Handbook of N.Z. Mines, 1887, p. 221). Dr. Gaze himself mentions the presence of stream-tin at Cedar Creek and Mokihinui (*op. cit.*, p. 46). These localities, especially the latter, are doubtful; but the mineral certainly occurs in the Mackley Valley (see page 122). Sydney Fry found stream-tin in sluice-box concentrates at Waimangaroa (Kenneth Ross, *op. cit.*, p. 12), and McKay reports it as found with gold in the Upper Waimangaroa Valley ("Gold-deposits of New Zealand," 1903 (reprint), p. 24).

Chalcopyrite: The Handbook of N.Z. Mines, 1887, states (p. 221) that loose pieces of copper-ore were found at Nine-mile Hill, ten miles from Westport, and also that a cupriferous reef was discovered "up the Buller Road fourteen miles from Westport."

Chlorite: A common secondary mineral in almost all the igneous rocks. Small bands of chlorite-bearing schist outcrop in several branches of the Orowaiti River (Giles Creek). Penninite is the only variety noted. A green foliated mineral occurring in the schists of the Mokihinui district may be clinochlore. A chloritic mineral occurs with quartz in the Beaconsfield lode, Waimangaroa Gorge.

Chromite: Occurs as water-worn grains in sluicing concentrates from Fairdown Terraces, and is doubtless present at Bradshaw's, Addison's, &c. (See analyses quoted on pages 115–17.)

Clay: Not strictly a mineral. (See pages 128–30, and Kaolin.)

Clinochlore: See Chlorite.

Coal: Not strictly a mineral. Bituminous coal, glance or pitch coal, brown coal, and lignite all occur in the subdivision. (See Chapter VI, and Jet.)

Coke, Natural or Native (Carbonite): Seddonville. (See page 171.)

Copper-pyrites: See Chalcopyrite.

Cordierite: See Iolite.

Cryptoperthite: See Anorthoclase.

Dreelite: See Barite.

Epidote: Occurs in some diorites and gneisses; for example, in the gneissic diorite of West Creek, near the Nine-mile Ferry, Buller River, more or less idiomorphic epidote is plentiful.

Galena: McKay states ("Gold-deposits of New Zealand," 1903, p. 27) that a galena-bearing reef has been discovered in Cascade Creek valley. This is probably the same lode as that mentioned by Cox (Rep. G.S. during 1874–76, No. 9, 1877, p. 28) as containing "principally an alloy of antimony and lead, sulphur occurring in it only in small quantities." In 1910 three samples of galena-bearing material, forwarded by W. C. Ancell from the Buller district, on being assayed by the Dominion Laboratory (Lab. Rep. No. 44, 1911, p. 17) were found to contain 8·92, 17·77, and 21·45 per cent. of lead respectively. These samples, however, may not have come from the subdivision, no definite locality being stated.

Garnet: Present, but not abundant, in many gneissic and pegmatitic rocks. In the auriferous beach sands of the coast-line garnets are plentiful. The mineral is a constituent of the pegmatite dyke worked for mica at Charleston, of pegmatite in Pensini Creek, &c. Recorded from the vicinity of Charleston in Lab. Rep. No. 20, 1886, p. 43, and Lab. Rep. No. 29, 1895, p. 12.

Gas, Natural (Methane, &c.): Firedamp in some quantity was evolved in the workings of the old Wellington Mine, and in August, 1880, there was a severe explosion (Mines Report H.–12, 1881, p. 13). Young and Haylock's mine may also have been fiery. In other mines firedamp has been found, if at all, only in small amount—*e.g.*, at Millerton.

Gold: In quartz-veins at Stony Creek, Waimangaroa Gorge, Mokihinui Reefs (outside subdivision), New Creek, &c. (see Chapter VI). For the numerous alluvial occurrences see Chapter VI, pp. 112–22.

Graphite: According to Skey a sandstone from the Waimangaroa River contains graphite in non-commercial amount (Lab. Rep. No. 14, 1879, p. 28).

Hornblende: A constituent of the dioritic rocks. The brown amphibole in camptonitic rocks from the Blackwater River watershed appears to be barkevikite.

Ilmenite: Occurs in considerable amount in the beach (black-sand) deposits, ancient and modern, in river sands and gravels, &c. Some of the diorites contain a few crystals of the mineral.

Iolite (Cordierite): Schistose rocks and hornfels from the Mokihinui and other districts show white spots consisting of a spongy or granular mineral resembling quartz. This may be iolite, but no precise determination has yet been made.

Iron-ochre: Small deposits of hydrated ferric oxide due to springs are common. A mass of iron-oxide mentioned by McKay as occurring at the "cave" outcrop, Chasm Creek, was evidently of this nature. (See G.S. Rep. during 1890–91, vol. 21, 1892, p. 85.) Hydrated oxide of iron is the cementing material of the "hard-pan" beneath the pakihis, of the auriferous "cement," &c.

Iron-pyrites: See Pyrite.

Ironsand: See Magnetite, Ilmenite.

Jet: The occurrence of small masses of a jet-like mineral in the Denniston coal has been reported by Sydney Fry (Mines Report, C.–3, 1906, p. 30, and personal communication), who quotes the following analysis: Fixed carbon, 27·8; volatile hydrocarbons, 69·8; water, 0·8; ash, 1·6. Thus the material is apparently a variety of cannel coal. It has, however, the physical characters of jet.

Kaolin: Has been found in a comparatively pure state filling cracks in the Denniston coal (Sydney Fry in Mines Report, C.–3, 1904, p. 27).

Labradorite: A common constituent of the intermediate and basic igneous rocks.

Leucoxene: A somewhat rare alteration product of the titaniferous iron-ore of some igneous rocks.

Limonite: Common as rusty stains, &c. (See also Iron-ochre, &c.)

Löllingite: Occurs at the Victory Mine, New Creek. (See pp. 110–11.)

Magnetite: Occurs in scattered crystals in the diorites and lamprophyres, and is abundant in the ironsands of the modern and raised sea-beaches. Here it is usually titaniferous, and, in fact, much of the black sand is ilmenite. Occasionally ironsand is mistaken for tin-ore—see, for example, Lab. Rep. No. 20, 1886, p. 44, where Skey reports being unable to find tin in black-sand from the vicinity of Westport, which had been alleged to contain that metal in large proportion.

Manganese-ore: Reported from the Buller River [valley] in the Handbook of N.Z. Mines, 1887, p. 221, but the exact locality is not stated. (See also Rhodonite.)

Marcasite: This form of iron-bisulphide is probably fairly abundant in the coal-measures (see also Pyrite).

Mercury, Native: Many years ago metallic mercury was reported from a water course near Westport at a place well removed from any gold-workings. Most probably, however, it had escaped from some gold-saving appliance, or had been accidentally spilt by some miner. (See Lab. Rep. No. 9, 1874, p. 23.)

Mica: See Biotite, Muscovite.

Microcline: A very common feldspar in the granite and associated acid igneous rocks of the subdivision.

Monazite : In 1905 Sydney Fry announced the probable presence of this mineral in concentrates from Bradshaw's Terrace. This determination was confirmed by the Colonial (Dominion) Laboratory, which found 2 per cent. of rare earths (mainly ceria with some thoria) and phosphoric acid in similar concentrates (Lab. Rep. No. 40, 1907, p. 25). The presence of rare earths has also been detected by the Dominion Laboratory in samples of concentrates from Dennehy's claim, Bull's (see page 116); from McCann's and the Shamrock sluicing claims; Addison's (see page 115); and from the head of Cedar Creek, Mount William Range. Sydney Fry also found minute quantities of monazite in gravels south of the Whareatea (Kenneth Ross, *op. cit.*, p. 12).

Muscovite : A constituent of most of the igneous rocks, and of the schists, hornfels, &c. Some pegmatite veins, as at Charleston, contain large plates of the mineral. (See also pages 124–25.)

Oligoclase : Common in the granites, quartz-porphyries, and other acid-igneous rocks.

Olivine : Has been noted in the lamprophyres of the Blackwater River valley.

Orthoclase : A prominent constitutent of the granites, gneissic rocks, and quartz-porphyries.

Osmiridium : H. A. Gordon reports that osmiridium, associated with alluvial gold, has been found near the mouth of the Mokihinui River (Mines Report, C.–5, 1888, p. 36; "Miners' Guide," second edition, 1906, p. 15). The alloy may also occur in the Whareatea River gravels (*Mines Record*, vol. iv, 1900–1, p. 161).

Penninite : See Chlorite.

Platinum : In 1904 Sydney Fry found platinum in gold bullion from the Rochfort Hydraulic Sluicing Claim (Mines Report, C.–3, 1904, p. 27). He also determined the metal in concentrates from Christmas Terrace (Fairdown), German Creek [German Gully], the "back lead near the beach," and Bradshaw's Terrace (Kenneth Ross *op. cit.*, p. 12). The Dominion Laboratory has identified platinum in sand from German Terrace, forwarded by A. D. Bayfeild (Lab. Rep. No. 42, 1909, p. 31) and in concentrates from Fairdown (see p. 117).

Proustite : Determined by Sydney Fry in sluicing concentrates from Waimangaroa (Kenneth Ross, *op. cit.*, p. 12).

Pyrite (Iron-pyrites) : The diorites of the subdivision usually contain a few crystals, and the granites, gneisses, and other rocks are occasionally locally pyritized. In the bituminous coal-seams iron-bisulphide is locally abundant, sometimes forming large irregular concretionary masses, similar to those seen in the Point Elizabeth State Colliery (see N.Z.G.S. Bull. No. 13, 1911, p. 114). Pyritic concretions are not uncommon in the shale (Deep Creek, Cascade Creek) and sandstone (near Mine Creek) of the Brunner beds, and in the lower horizons of the Kaiata beds (Chasm Creek, &c.). The concretionary material may well be marcasite in whole or more probably in part.

Quartz : Common everywhere. Numerous veins occur in the argillites and greywackes of the Waimangaroa, Mokihinui, and other districts.

Rare Earths (Thoria, Ceria, &c.) : See Monazite, and Chapter VI, pp. 115–17, 123.

Retinite (Mineral Resin) : Common in the lignites of the Charleston district and Tauranga Bay; in the brown coal of Pensini Creek, &c. Occurs more or less commonly in the Seddonville and Mokihinui coal, and much more rarely in the Coalbrookdale coal. (See also Chapter VI.)

Rhodonite : Found by Sydney Fry in gravels south of the Whareatea (Kenneth Ross, *op. cit.*, p. 12).

Rutile : Very fine needles of rutile are plentiful in the quartz of the Mokihinui granites. Similar needles may be frequently observed in the biotite and less commonly in the hornblende occuring as rock-constituents.

Sericite : A common decomposition product of feldspar. Occurs also as small flakes in hornfels.

Serpentine : Found only in small quantities as an occasional alteration product of some minerals in the igneous rocks. The iron-rich variety iddingsite (or bowlingite*) represents the original olivine in some of the Blackwater River lamprophyres.

Spathic iron-ore (Siderite): Samples of spathic iron-ore from the vicinity of Westport were analyzed by Skey in 1873 (Lab. Rep. No. 9, 1874, pp. 22–3). Lab. Rep. No. 22, 1887, p. 48, gives analysis of a sample from Mokihinui collected by McKay, and Lab. Rep. No. 35, 1902, p. 12, of another sample "from Westport." The various analyses show mixtures of lime, iron, and magnesium carbonates, containing only from 12 to 15 per cent. of iron.

Sphene : See Titanite.

Spinel : Magnesian spinel has been identified by Skey in a "wash" from Westport, forwarded by Dr. Gaze (Lab. Rep. No. 29, 1895, p. 12).

Stibnite (Antimonite): Recorded from Westport district by Skey (Lab. Rep. No. 11, 1876, p. 18) and Cox (see under Galena). Skey mentions previous samples from the same district. The mineral has also been reported from the Buller River (Lab. Rep. No. 17, 1882, p. 35), but the exact locality is not known.

Stream-tin : See Cassiterite.

Sulphur : Forms as a product of the decomposition of pyrite and other sulphur-bearing compounds in the coal-seams, and was especially observed as deposited round steam-vents above the burning Mokihinui coal. In this connection it should be noted that some (if not all) of the coals of the district on being heated emit sulphuretted hydrogen,† which when acted on by steam forms free sulphur.

Talc : Present in some igneous rocks, where it represents an alteration product of olivine or hornblende.

Thallium : Dr. Gaze records this element as present in small quantity in iron-pyrites from Mokihinui Reefs (*op. cit.*, p. 60).

Titanite (Sphene): Occurs in minute sparse crystals in several granites, and in coarser irregular crystals and strings in some diorites.

Topaz : A pebble forwarded by Dr Gaze from Westport was determined by Skey as topaz (Lab. Rep. No. 23, 1888, p. 55).

Tourmaline : Occurs in granites, pegmatites, and in hornfels (Mokihinui district). Pegmatitic boulders containing tourmaline were observed at Charleston, in Mount William Creek, in Plateau Creek, in Tiger Creek, in the Mackley River, and in Pensini Creek. Pebbles of a highly basic schorl-rock occur in the gravels of the Mokihinui River.

Tremolite : Found in small amount as an alteration product of olivine in camptonites and apparently of amphibole in some diorites.

Uralite : Recognized in a dolerite found in creek-gravels near the new inland Karamea–Mokihinui Road. The spongy bluish-green hornblende of some diorites is probably uralite. (See Chapter V, p. 104.)

Water, Mineral : There are numerous small "iron" and other springs in the subdivision. (See Chapter III, p. 57.) No. 2 bore, Charming Creek, yields a fair flow of slightly mineralized water, and the Fairdown bore (Westport Coal Company) gives a large flow of water tasting of iron-sulphate and possibly of common salt.

Wolframite : Determined by Sydney Fry in a solitary specimen from sluice-box concentrates at Waimangaroa (Kenneth Ross, *op. cit.*, p. 12).

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* W. N. Benson states that bowlingite, according to Lacroix, is probably identical with iddingsite and that the former name should have priority. See "Petrographical Notes on Various New South Wales Rocks," Proc., Linn. Soc., N.S.W., vol. xxxix, pt. 3, 1914, p. 473.

† For example the coal from the old Westport-Cardiff Mine (W. P. Evans), and the Charleston lignite (Dominion Laboratory).

Wollastonite: A boulder of garnetiferous contact-altered calcareous rock collected from gravels in the lower Buller Valley contains a mineral that from its optical properties appears to be wollastonite.

Zircon: Occurs as minute and rare crystals in most of the igneous rocks of the subdivision. The concentrates from sluicing claims always contain a moderate amount of this mineral, and it is doubtless present in all gravels and sands. No dish prospect was ever taken by the Geological Survey party without some zirconiferous sand being observed in the pannings. The mineral when once known may generally be easily recognized as a heavy shining sand, of a characteristic light-greyish colour with a tinge of red. The earliest identification of zircon in the district seems to have been made by Sydney Fry in gravels south of the Whareatea. (Kenneth Ross, *op. cit.*, p. 12.)

APPENDIX II.

CORRIGENDA AND ADDENDA.

Besides the accidental omissions inseparable from a lengthy report of a geological survey extending over several years, many observations made during the course of the fieldwork in the Buller-Mokihinui Subdivision have been more or less intentionally omitted from this bulletin, principally on account of the lengthy descriptions necessary to embody them. Again, owing to the exigencies of space, numerous strikes, dips, barometric heights, and other data have been excluded from the published maps. In particular, had the scales permitted, W. M. Cooper's survey stations and barometric heights, together with the whole of R. B. Denniston's outcrops, would have found a place on the maps, and thus a considerable amount of information now almost inaccessible rendered available to the miner and surveyor.

The following list, though far from complete, contains various corrections and additions (mainly to the maps) that may be of some service to the reader.

Mokihinui Survey District.

The islets west of the Kongahu (Lower Buller) fault north of Three-mile Creek (the Grenadier Rocks) are composed of Miocene limestone and calcareous conglomerate. Seal Rock (or Rocks), to the north near Kongahu Point, is probably also formed of Miocene rocks.

Salt-water Creek, mentioned by Burnett (1863), is probably Brewery Creek (tributary of Mokihinui River). If Denniston's Salt-water Creek (page 171 of his report) is the same, search for the loose coal and coal-measure grits reported by him in the bed of the creek 40 chains from the Mokihinui is desirable.*

Hunter's Creek, of Burnett's 1863 report, may be the stream near Mokihinui Railway-station named Marris Creek by the Geological Survey. Burnett's Stony Creek is probably Sawyer (or Sawyer's) Creek (west of Stillwater Creek). Near this creek Burnett observed ironstone nodules.

Roche's Creek (near Chasm Creek), mentioned by Denniston, has not been identified.

Page's Creek of the early reports is Chasm Creek.

Hodge Creek, shown on map south-east of Mount Kilmarnock, should be Hodges Creek.

The height of 1,360 ft. shown about a mile up Welcome Creek (or Welcome Bay Creek) should be 1,160 ft. The patch of granite shown just above should extend a

* An old tracing, found since this was written, shows that Denniston's Salt-water Creek is Marris Creek of the present survey.

short distance downstream, and be represented about twice the size indicated on map Some rock that is probably a fine-grained granite was taken in the field for a re-crystallized sedimentary rock, and mapped as belonging to the Aorere series.

Ngakawau Survey District.

Crane (or Crane's) Cliff, mentioned in various reports, overlooks the Ngakawau River north-east of the mouth of Mine Creek.

The more easterly of the two faults shown crossing the Ngakawau River near Mine Creek mouth extends some distance farther to the south than mapped.

Round Hill, mentioned by Denniston, is Cooper's station T 100, and is south-south-west of Darlington in the prominent bend of the Westport-Stockton Company's tramline.

Ford Creek, a small tributary of the Mangatini, drains the country east of the Westport-Stockton Company's C and D tunnels.

The height of 2,280 ft. 50 or 60 chains north of Mount Augustus should be 2,880 ft., and that of 2,130 ft. to the south should be 3,130 ft.

A small patch near the mouth of T 31 Creek (tributary of St. Patrick Stream) is coloured as Aorere rock, but should be mapped as gneiss. Possibly also the small patches to the north coloured as Aorere should be mapped as gneiss. The outcrops were not closely examined.

Veins and small patches of granite, gneiss, and schist are associated with the rocks mapped as Aorere near and north of Cypress Stream (tributary of Upper Waimangaroa).

Happy Valley of Cooper's map is a flat drained by Cypress Creek and St. Patrick Stream. It lies south and east of the area of Aorere rocks mentioned above.

Cedar Creek of Cooper's map is Darcy Creek of the present bulletin. It is a tributary of Erin Creek, which flows into St. Patrick Stream. The name was changed to avoid confusion with the Cedar Creek (tributary of Waimangaroa) near Mount William.

Tio Creek of Cooper's map and of Cox's and Denniston's reports is not the Orikaka or Mackley River, but the more westerly branch of the Blackburn headwaters. The name is believed to be an adaptation of T 10. Many streams were named by Cooper from his stations—*e.g.*, T 31 Creek, V 8 Creek, &c.

Divide Creek of Denniston's report is the more easterly branch of the Blackburn headwaters.

Orikaka Survey District.

Tiger Creek pakihi is between the lower part of Tiger Creek and the Mackley. The barometric heights observed on the pakihi vary from 1,280 ft. to 1,420 ft.

The geological map does not show the gravels that cover Feddersen's flat (at bend of Buller in south-east corner of Orikaka Survey District) and form terraces on the west side of the Buller near New and Pensini Creeks.

The bridge ("steel bridge") shown across the Buller east of Feddersen's is the "Lyell Bridge" of Chapter V, near which various Miocene fossils were collected by the old Geological Survey (long before the erection of the bridge).

Lyell Survey District.

The mapping of the fault-involved patches of Miocene rocks in Tichborne Creek valley is unsatisfactory, but circumstances hardly permitted of more correct work. The following statement is a summary of information supplied by Dr. J. Henderson:—

The Aorere rocks in Tichborne Creek consist of alternating bands of knotted schistose hornfels (the knots being almost certainly co dierite) and quartz-mica hornfels.

A quartz-lode less than half a mile up the stream, and at least 10 ft. wide, shows much mica towards its margin, thus suggesting a relationship with the acid dykes of the district. It is evidently connected with a still larger lode in New Creek, whether as a branch or as a continuation is uncertain. A lode crossing the stream a few chains farther up, which is said to be the vein worked by the Sir Charles Napier Company, is from 18 in. to 24 in. wide.

Kawatiri Survey District.

Nikau Creek of Cooper's map is Stony Creek (north of Waimangaroa).

Waimangaroa Village is on railway-line to Conn's Creek, east of Waimangaroa Junction.

The terraces from the Buller River north-east to Whareatea River are generally known as the Fairdown Terraces. On Cooper's map the name "Fairdown Terrace" is restricted to the ground between Whareatea River and Lake Creek. South of the Lake Creek is Greenhill Terrace; south of Christmas Creek is Christmas Terrace; and south of Hatter's Creek is Hatter's Terrace. Hatter's Creek is a branch of Christmas Creek. Caledonian Terrace on Cooper's map is north of Ballarat Creek near trig. station YY. Richly auriferous gravel was worked here about 1867.

Jones Creek of Cooper's map is the more southerly (main) branch of Ballarat Creek. The name is omitted as apparently not now in use, and in order to avoid confusion with Jones Creek near Birchfield.

Todea Creek of Cox and Denniston is Cascade Creek (south of Coalbrookdale).

The surveyed branch of Vincent Creek (south-east of Mount Rochfort) was given the name of Edgar Creek by the Geological Survey.

The grits near trig. station M strike 173°, and have a westerly dip of 22°.

In the upper part of Wright or Coal Creek thick conglomerate outcrops.

The barometric height obtained at Lake Rochfort was 1,560 ft. Cooper's height, very close to the lake, is 1,545 ft. Many other barometric heights could be added to the published map from the field map—*e.g.*, in Christmas Creek, the north and south branches of the Orowaiti, in Cascade Creek valley, &c.

Waitakere Survey District.

The lignite-outcrops west of Charleston near Constant Bay are not shown on the map.

Ohika Survey District.

The thin coal-seams on the roadside north-east of Hawk's Crag are not shown on the map. They occur about 14 chains north of the boundary between Eocene and Miocene rocks (the distance being measured along the east or left bank of the Buller). The coal strikes 326°, and dips at 75° to the south-west. Overlying sandstone and conglomerate strike 336°, and have a dip near 90°. The strata are fault-involved.

Small mineral springs are reported to exist near Hawk's Crag.

Map of the Buller Coalfield.

The worked areas shown in solid grey are from Mines Department maps. The stippled areas are approximate only.

In consequence of the lenticular nature of the coal-seams it was not considered advisable to show the boundaries of the workable coal. To do so would require much additional survey and the construction of thickness-contours.

A small area of hornfels near the junction of Mossy Creek with the Mackley (Orikaka Survey District) is coloured as granite, instead of as Aorere rock.

CORRIGENDA AND ADDENDA.

(See also pp. 196–198.)

Page vii: To list of maps add, "Map of the Buller-Mokihinui Subdivision showing Fault-lines." The name "Mount Frederick" has been omitted from this map.

Figure 12A (at end): "Washout (?)" should be placed nearer the right-hand side of the figure.

Page 66: A footnote may be added to the effect that the figures mentioned in paragraphs 2 and 3 will be found at the end of the bulletin.

Page 70, line 5 from bottom: *For* "satisfy the alkalies" *read* "satisfy the lime and alkalies."

Page 78, line 4: *For* "intermixed" *read* "intergrown."

Page 87: To the discussion on the unconformity between the bituminous coal-measures and the Oamaru Series a brief description of the contact on the road between Waimangaroa and Denniston Junction (see Trans., vol. xlvi, 1914, p. 275) may be added. The strata are steeply dipping and involved in the Lower Buller fault, but little sign of movement can be seen at the contact itself, which is marked by a very slight irregularity and by a few small pebbles of granite and other rocks (including a piece of Kaiata mudstone), together with some calcareous concretions, the latter probably derived from the Kaiata mudstone. An erosion surface is thus indicated. The scarcity of pebbles is explained by the Kaiata mudstone being too soft to form pebbles whilst being eroded.

Page 87, paragraph 2: In explanation and extension of the latter part of this paragraph the following sentences may be inserted: "Since remnants of the Kaiata beds still overlie the Brunner beds in various elevated localities, for example near Burnett's Face, the reader may conclude with almost absolute certainty that these beds were everywhere deposited before elevation of the bituminous coal-measures commenced. Hence the erosion of the Brunner beds that produced the water-worn coal did not begin at any point whilst elsewhere deposition of the Kaiata beds was continuing, and therefore contemporaneous erosion is inapplicable. In the light of further evidence obtained from the Reefton Subdivision, joined to a careful reconsideration of all available data, the senior author would add that the case for unconformity between the bituminous coal-measures and the Oamaru Series can be established beyond a doubt."

Page 102, line 7 from bottom: *For* "Basic boulders" *read* "Dark-coloured boulders."

Page 106, paragraph 3: The so-called glass of the monchiquite from Rider Creek may possibly be analcite.

Pages 131–32, 172: Under the heading of "Physical Characters" the specific gravities of the various coals are not mentioned, but specific-gravity determinations will be found on pages 134, 135, 139, 150, 173, and 175.

Page 141, paragraph below analyses: The composition of the "volatile hydrocarbons" of weathered coal requires study. There is reason to believe that they include much water not expelled at 100° C., and therefore that the statements made in this paragraph require modification.

Page 167, line 12 from bottom: *For* "Denniston and Cooper" *read* "Hector, who derived his information from Denniston and Cooper's surveys."

Page 175, line 13: *After* "quoted" *insert* "in addition to those given on page 173."

INDEX.

A.

B.

C.

D.

E.

H.

I.

J.

K.

L.

M.

N.

O.

* This is the spelling of the official records. The name is more correctly spelt "Whareatea."

Y.

Z.

By Authority: John Mackay, Government Printer, Wellington.—1915.
[700/12/14—20435

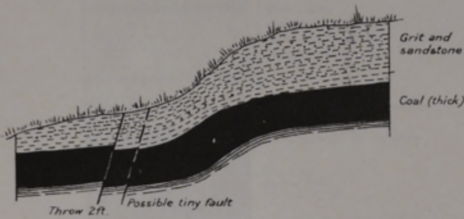


Fig. 1

Mangatini Roll Fault, as seen near Mangatini.
The section is partly ideal

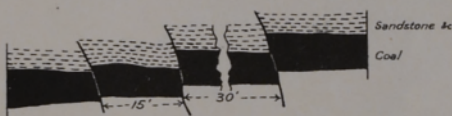


Fig. 2

Reversed Faults near Westport-Stockton bridge.
between B & C tunnels

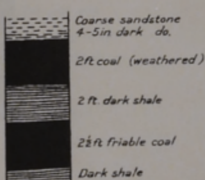


Fig. 3A

Section at 560ft on ridge
SW of Chasm Creek.

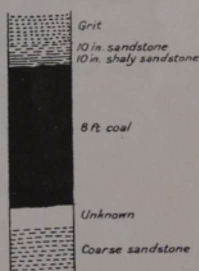


Fig. 3B

Section at 615ft on ridge
SW of Chasm Creek.

G.E.H.

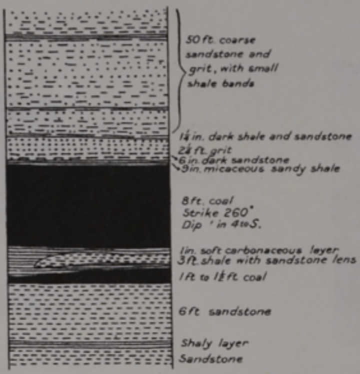


Fig. 4

South bank of Chasm Creek
near Dove's Drive

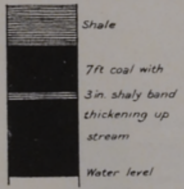


Fig. 4A

Chasm Creek
50 chs above Y.S.P.E. Coy's
tram bridge

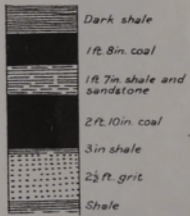


Fig 4B

Chasm Creek
1 ch. above section 4A

G.E.H.

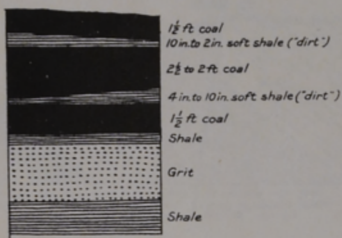


Fig. 5

Y. S. P. E. Co's tram line near Mokihinui Mine.
About 5 ft 3 in coal and 1 ft dirt bands.

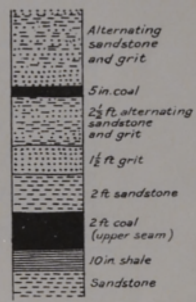


Fig. 6

Charming Creek
a little below No 1 Bore

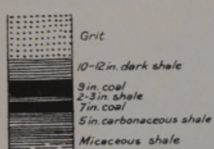


Fig. 7A

Section 2½ miles above mouth of Blackburn R.

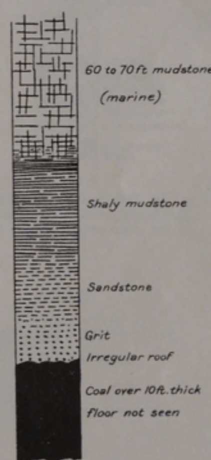


Fig 7 B

Near Blackburn R.
a few chains above section 7A

G.E.H.

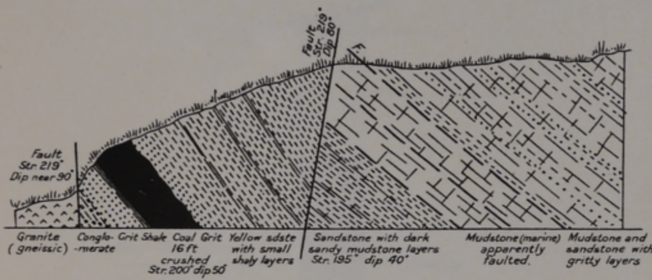


Fig. 8

Idealized section, south bank of Ngakawau River, below Mine Creek Junction.

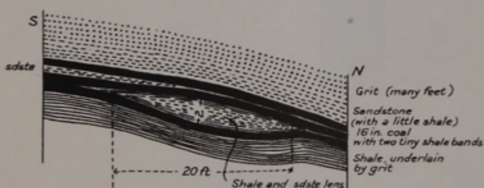


Fig. 9A

Section on west side of Mangatini Creek gorge, about 1100 feet above sea-level, showing grit and sandstone lenses in small coal seam.

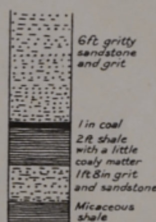


Fig. 9B

Section on west side of Mangatini Creek gorge, a few chains above sec. 9A

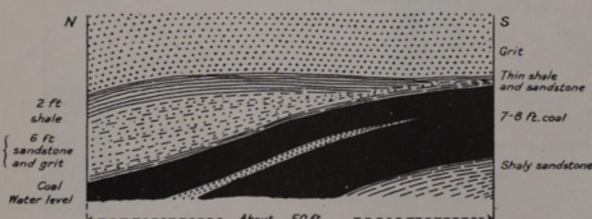


Fig. 9C

Section on east side of Mangatini Creek gorge, a few chains above section 9B

G.E.H.

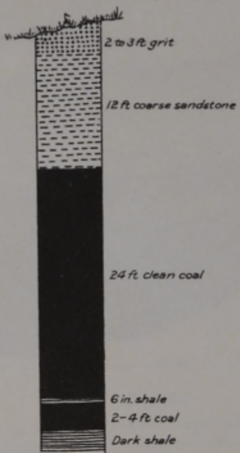


Fig. 10

Near Mangatini township on south side of Mangatini Creek.

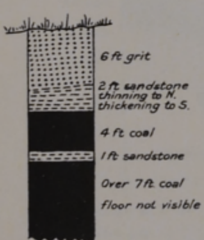


Fig. 11 A
Section near Westport-Stockton D tunnel

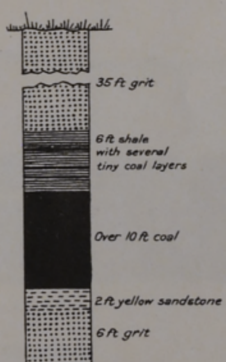


Fig. 11 B
Section 2 chains north of section 11A

G.E.H.

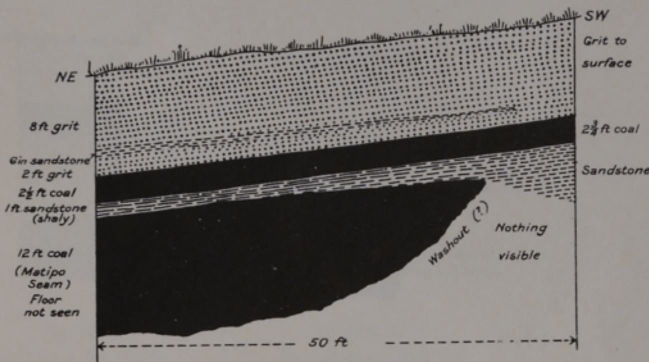
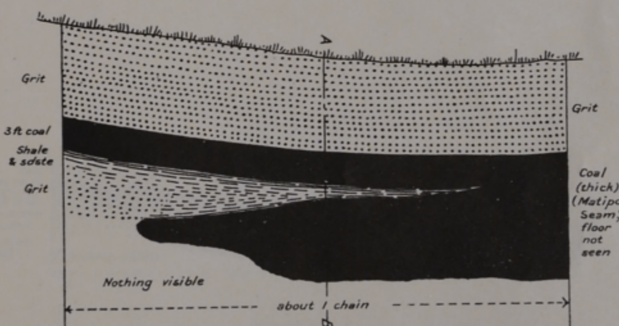


Fig. 12 A

Section a few chains NW of coal island near T31 Creek, eastern part of Westport-Stockton Lease.



Section at A-B
10 ft grit
3 " coal
1½ " shale
10 " or more of coal

Fig. 12 B

Section two or three chains south of section 12A.

Vertical scale slightly exaggerated.

G.E.H.

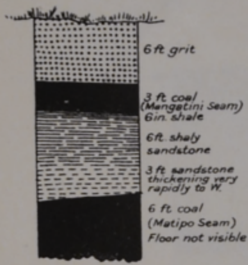


Fig. 12C
Section a few chains north of section 12A

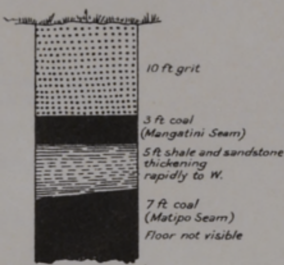


Fig. 12D
Section about 60ft east of section 12C.

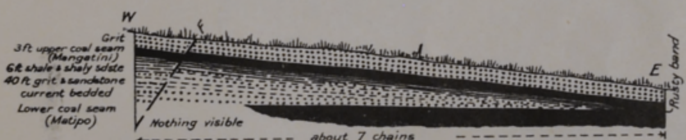


Fig. 12E
Generalized section, including sections 12C & 12D.

G.E.H.

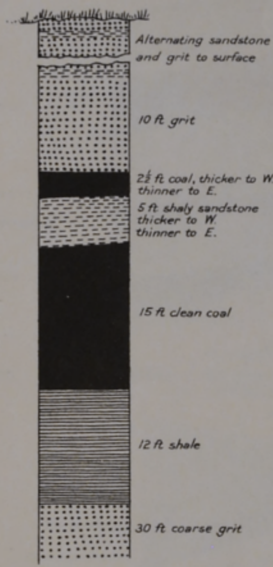


Fig. 13

Section in upper Fly Creek

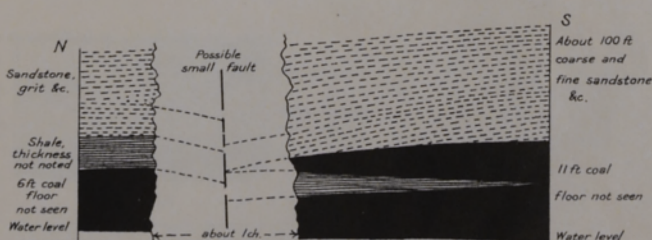


Fig. 14

Section on east bank of Waimangaroa River, near "Cook's Lease"

G.E.H.

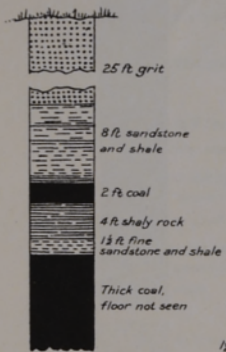


Fig. 15A
Section near iron bridge, Burnett's Face.

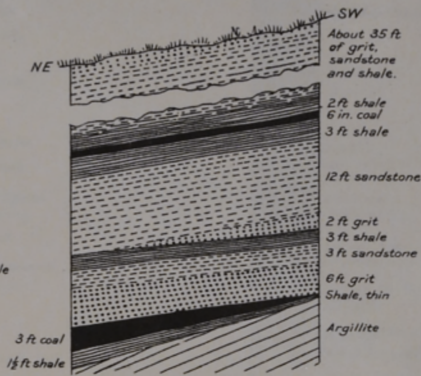


Fig. 15B
Section a few chains to the SE of section 15A.

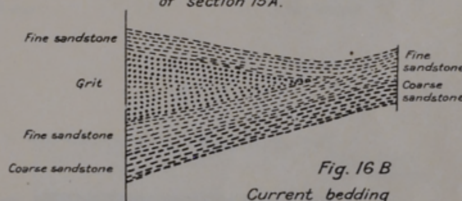


Fig. 16 B
Current bedding near section 16A.

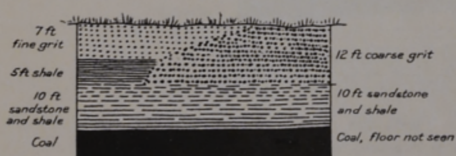


Fig. 16A
Current bedding, road cutting east of Burnett's Face

C.E.H.

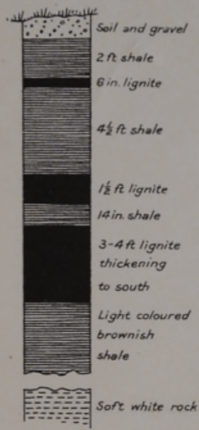


Fig. 17
Section 1¼ miles south of Charleston

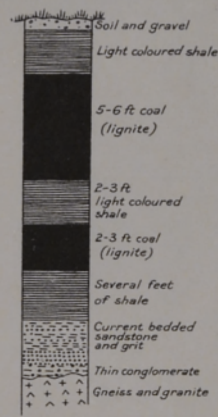


Fig. 18 A
Section near Constant Bay Charleston

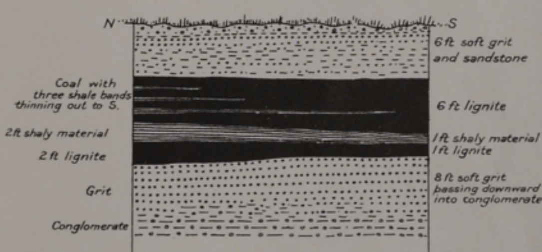


Fig. 18 B
Section a few chains N. of section 18A

G.E.H.

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e Buller-Mokihinui Subdivision

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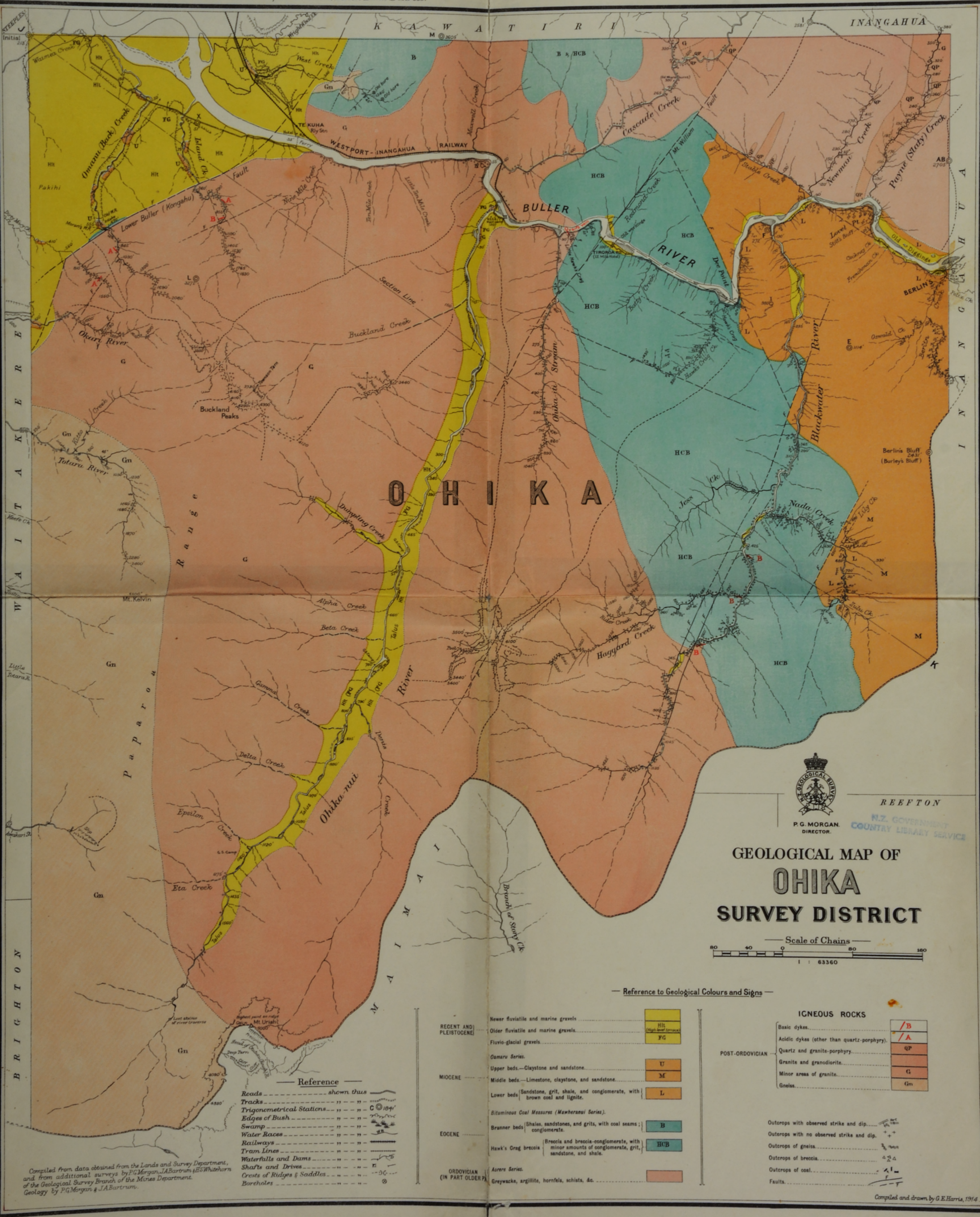
add maps

KAWATIRI
Westport Coal Co.
285a. 2r. 07p.
Westport-Stockto
1999a. 3r. 20p.
MANGATINI
Kerr Creek
Worley Creek
Jones Creek
Overflow
BIRCHFIELD
High Level Terrace
Low Terrace
Fan Creek
Boundary of Bull Coalfield
BRITANNIA ROAD (Dray)
Kiwi Creek
WAIMANGAROA JUNCTION
WAIMANGAROA VILLAGE
Old Koranui Tram
WESTPORT-SEDDONVILLE ROAD
Rapid Ck.
Stony Creek
Organ's Spur
Britannia Creek
Quartz Veins
Mt. Frederick
Fly Creek
Whareatea Ck.
Waimangaroa River
Webb Fault
Herbert Creek
Webb Creek
Cypress Creek
(Cook's Lease)
Waimangaroa River
DENNISTON
Sandstone Creek
Rapid Creek
Deep Creek
Cedar Ck.
Mt. William Fault
Mt. William Range
Saddle
Stevenson Creek
Whareatea Stream
BURNETT'S FACE
Burnett
W. C. Co.
1563a. 3r. 36p.
W. C. Co.
79a. 3r. 07p.
W. C. Co.
315a. 2r. 07p.
COALBROOKDALE
Conglomerate Ck.
Trent Creek
Mt. William
Mt. William Creek
Mt. Rochfort
V8 Creek
V17 Ck.
Cascade Creek
Gn
B
K
Q
QP


Mt Stockton
St. Patrick Stream
Erin Creek
Blackburn Stream
NGAKAWAU RIVER
Roddy Creek
Coal Co.
Plover Creek
St. Patrick
Gullies and ridges
Mt Berners
Boundary of Buller Coalfield
Tiger Creek
Mossy Creek
Mackley (Orikaka) River
Archer Creek
Dooley Creek
ORIKAKA
Unsurveyed
Glasgow Fault
LYELL
Pikopiko Creek
Plateau Creek
Slug Creek
Fall Creek
Blue Duck Creek
Track to Three Channel Flat
New Creek
Blue Creek
Gravels overlie
BULLER R.

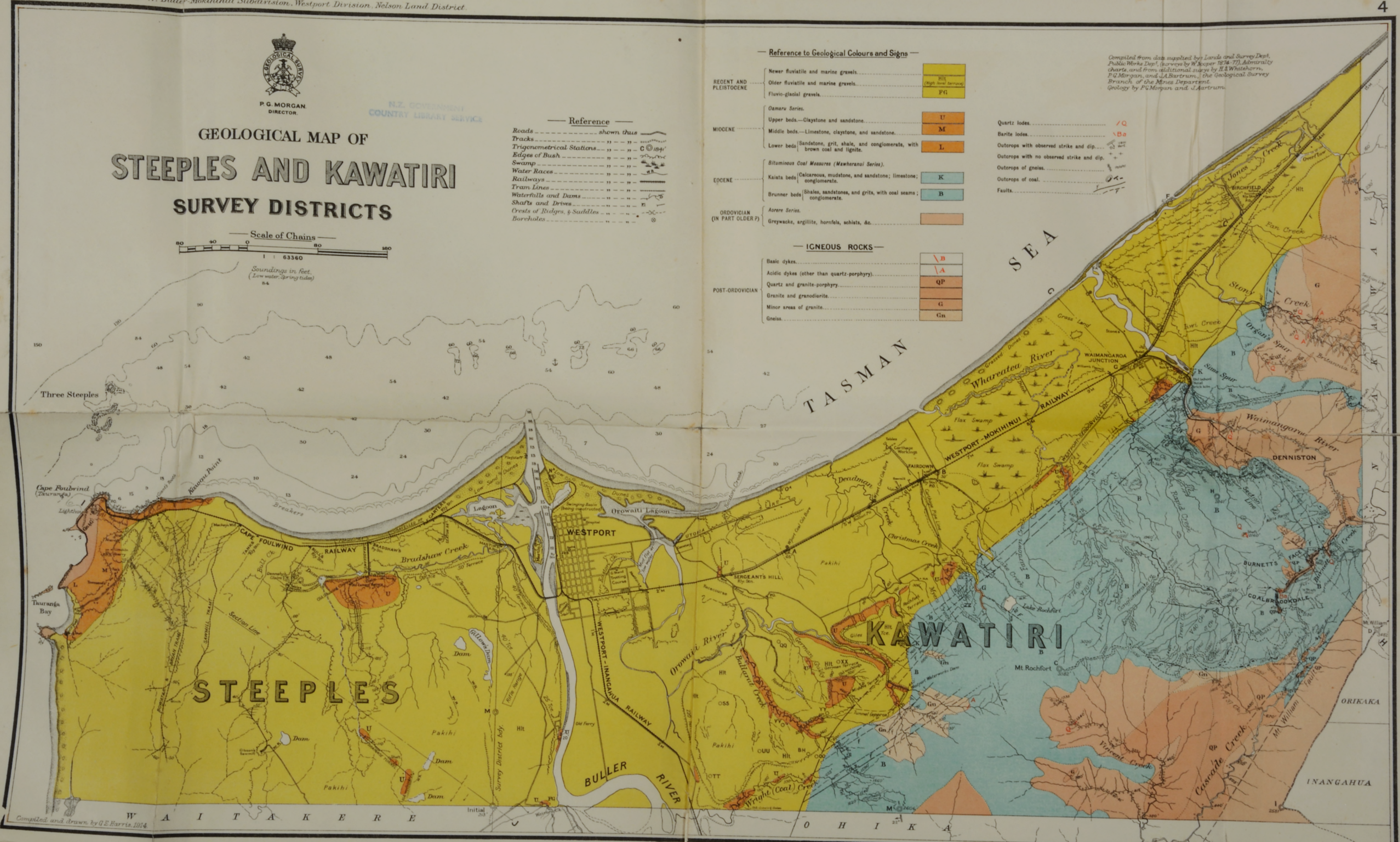

GEOLOGICAL MAP OF
OHIKA
SURVEY DISTRICT
P. G. MORGAN. DIRECTOR.
Scale of Chains
80 40 0 80 160
1 : 63360
REEFTON
KAWATIRI
INANGAHUA
WAITAKERE
BRIGHTON
MAIMAI
OHIKA
Paparoa Range
BULLER RIVER
WESTPORT - INANGAHUA RAILWAY
Blackwater River
Ohika-nui River
Ohika-iti Stream
Buckland Peaks
Mt. Kelvin
Berlins Bluff (Burley's Bluff)
BERLIN'S
TE KUHA
TIRONUI
Reference
Roads shown thus
Tracks
Trigonometrical Stations
Edges of Bush
Swamp
Water Races
Railways
Tram Lines
Waterfalls and Dams
Shafts and Drives
Crests of Ridges & Saddles
Boreholes
Compiled from data obtained from the Lands and Survey Department, and from additional surveys by P.G.Morgan, J.A.Bartrum & H.S.Whitehorn of the Geological Survey Branch of the Mines Department.
Geology by P.G.Morgan & J.A.Bartrum.
Reference to Geological Colours and Signs
RECENT AND PLEISTOCENE
Newer fluviatile and marine gravels
Older fluviatile and marine gravels
Hlt (High level terrace)
Fluvio-glacial gravels
FG
MIOCENE
Oamaru Series.
Upper beds.—Claystone and sandstone
U
Middle beds.—Limestone, claystone, and sandstone
M
Lower beds (Sandstone, grit, shale, and conglomerate, with brown coal and lignite.)
L
EOCENE
Bituminous Coal Measures (Mawheranui Series).
Brunner beds (Shales, sandstones, and grits, with coal seams; conglomerate.)
B
Hawk's Crag breccia (Breccia and breccia-conglomerate, with minor amounts of conglomerate, grit, sandstone, and shale.)
HCB
ORDOVICIAN (IN PART OLDER?)
Aorere Series.
Greywacke, argillite, hornfels, schists, &c.
IGNEOUS ROCKS
POST-ORDOVICIAN
Basic dykes
B
Acidic dykes (other than quartz-porphyry)
A
Quartz and granite-porphyry
QP
Granite and granodiorite
Minor areas of granite
G
Gneiss
Gn
Outcrops with observed strike and dip
Outcrops with no observed strike and dip
Outcrops of gneiss
Outcrops of breccia
Outcrops of coal
Faults
Compiled and drawn by G.E.Harris, 1914


SEA
MOKIHINUI
(KYNNERSLEY OR WAIMARIE)
MOKIHINUI
MOKIHINUI RIVER
SEDDONVILLE
ST HELENS
Pigeon Island
Chatterbox Ck.
Putten Creek
Dufty Ck.
Brewery Creek
Radcliffe Ridge
Frank Brook
Reed Brook
Stillwater
Tobin Creek
Pedges Ck.
View Hill Saddle
Creek
Murphy Creek
Burke Creek
Hauler Creek
Glasgow Fault
SEDDONVILE STATE
COLLIERY RESERVE
6503a 2r 3p
Charming Creek
Fletcher Brook
Chasm Creek
Coal (Pit Gorge) Creek
Watson Brook
Tate Creek
NGAKAWAU RIVER
Steep Creek
Rowse Creek
Mangatini Creek
Weka Creek
Repo Creek
DARLINGTON
Millerton Fault
Weka Ck.
Buller Coalfield
Boundary of
St. Andrew Stream
St. David Stm
St. George Stream
Election Creek
Budge Ck.
Glasgow Fault
NGAKAWAU

OF NEW ZEALAND No I

To accompany Bulletin No. 17, Buller-Mokihinui Subdivision, Westport Division, Nelson Land District.

4



To accompany Bulletin Nº 17. Buller-Mokihinui Subdivision, Westport Division, Nelson Land District.

P. G. MORGAN.
DIRECTOR.

MAP OF THE BULLER COALFIELD

SHOWING COAL-BEARING AREAS AND GENERAL GEOLOGY.

Scale of Chains

10 0 80 160 240

1 : 31680

Compiled and drawn by G. E. Harris, 1914.

Reference

Roads	shown thus
Tracks	" "
Trigonometrical Stations	" " C ◎ 1841'
Edges of Bush	" "
Swamp	" "
Water Races	" "
Railways	" "
Tram Lines	" "
Waterfalls and Dams	" "
[illegible]	" "
Crests of Ridges, and Saddles	" "
Boreholes	" "
Boundaries of Coal Leases	" "
Boundary of Buller Coalfield (From Lands & Survey Dept. maps)	"

Reference to Geological Colours and Signs

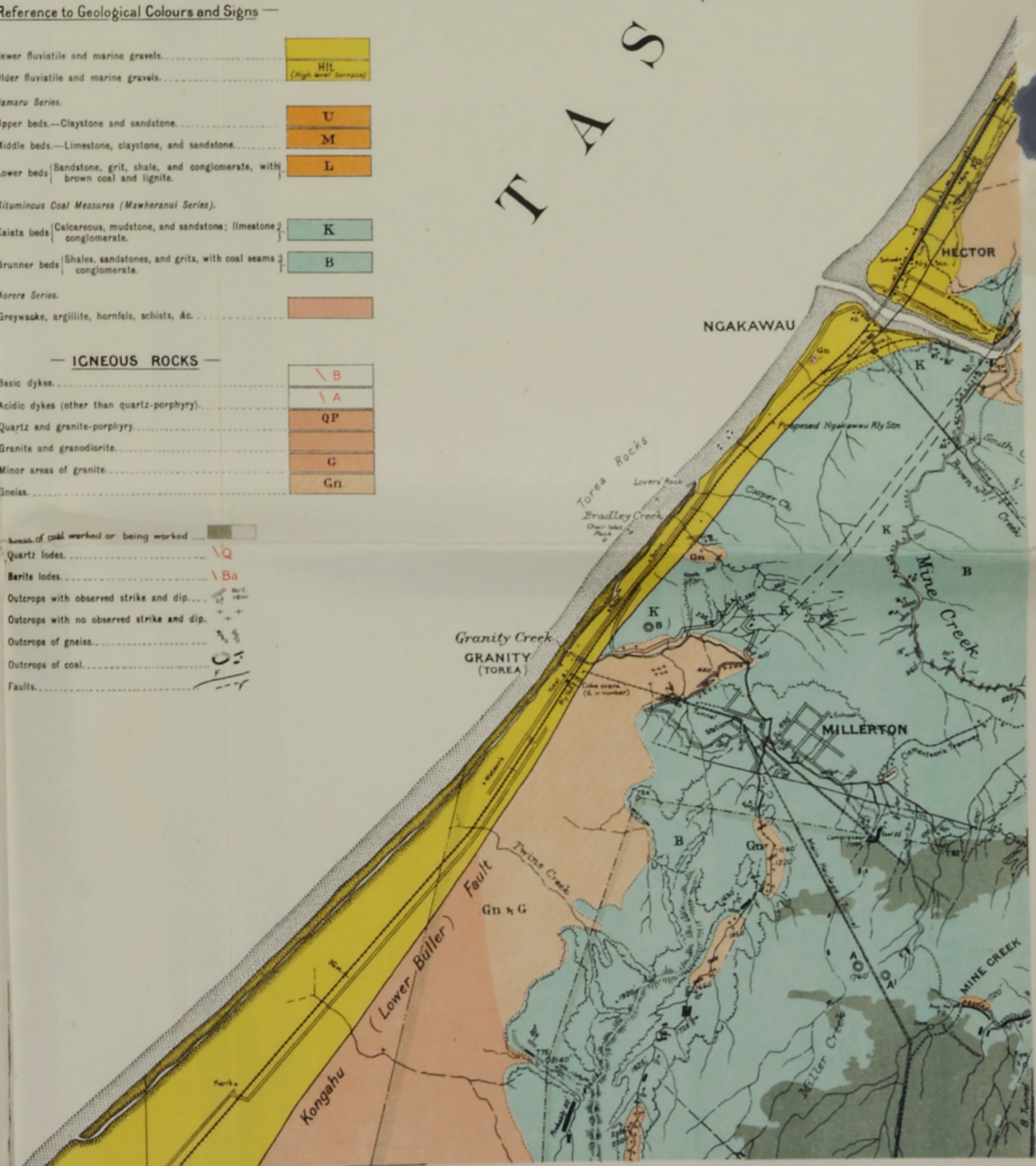
RECENT AND PLEISTOCENE	Newer fluviatile and marine gravels.	
	Older fluviatile and marine gravels.	Hlt (High level terrace)
MIOCENE	*Oamaru Series.*	
	Upper beds.—Claystone and sandstone.	U
	Middle beds.—Limestone, claystone, and sandstone.	M
	Lower beds {Sandstone, grit, shale, and conglomerate, with brown coal and lignite.	L
EOCENE	*Bituminous Coal Measures (Mawheranui Series).*	
	Kaiata beds {Calcareous, mudstone, and sandstone; limestone; conglomerate.	K
	Brunner beds {Shales, sandstones, and grits, with coal seams; conglomerate.	B
ORDOVICIAN (IN PART OLDER?)	*Aorere Series.*	
	Greywacke, argillite, hornfels, schists, &c.	

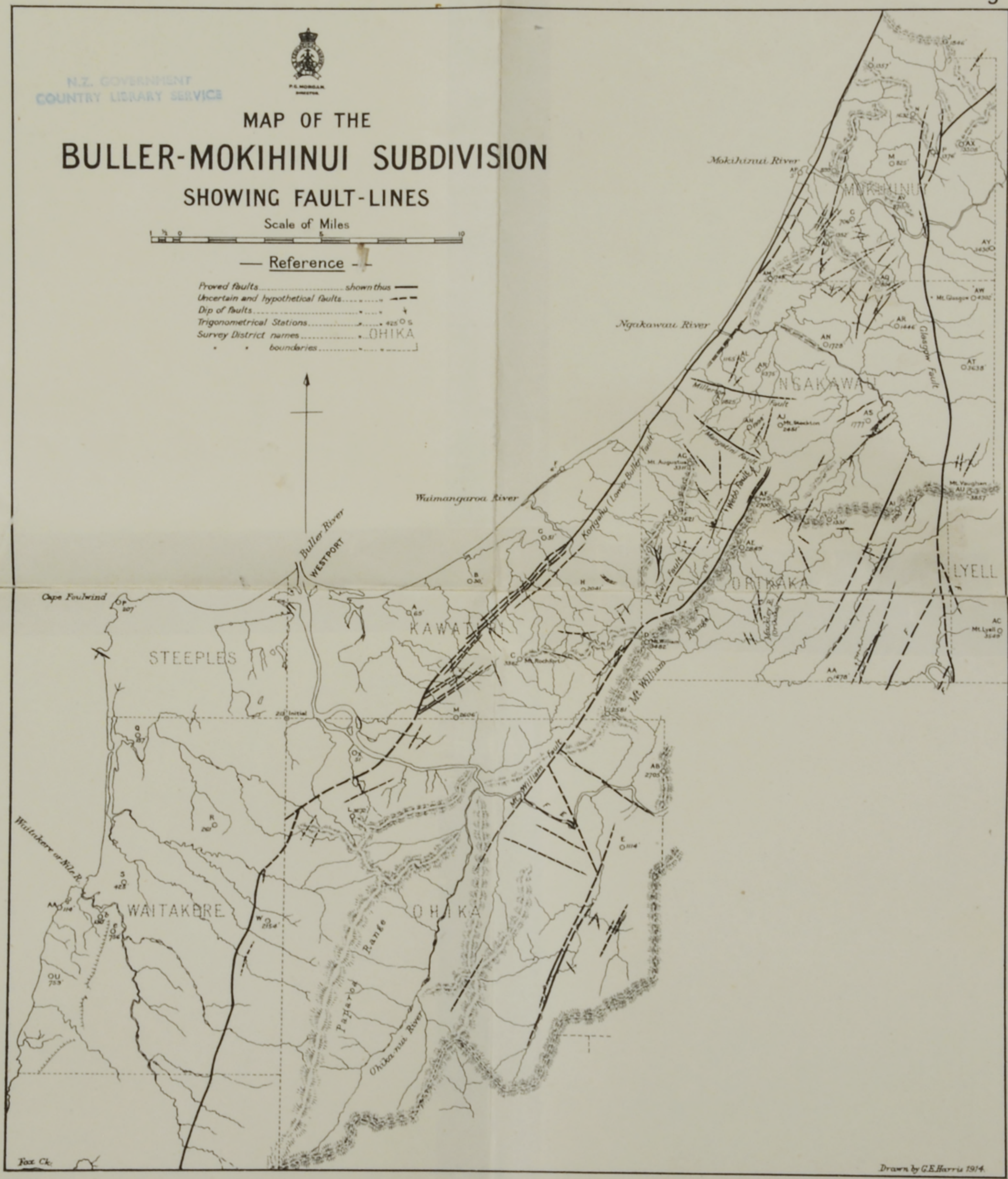
IGNEOUS ROCKS

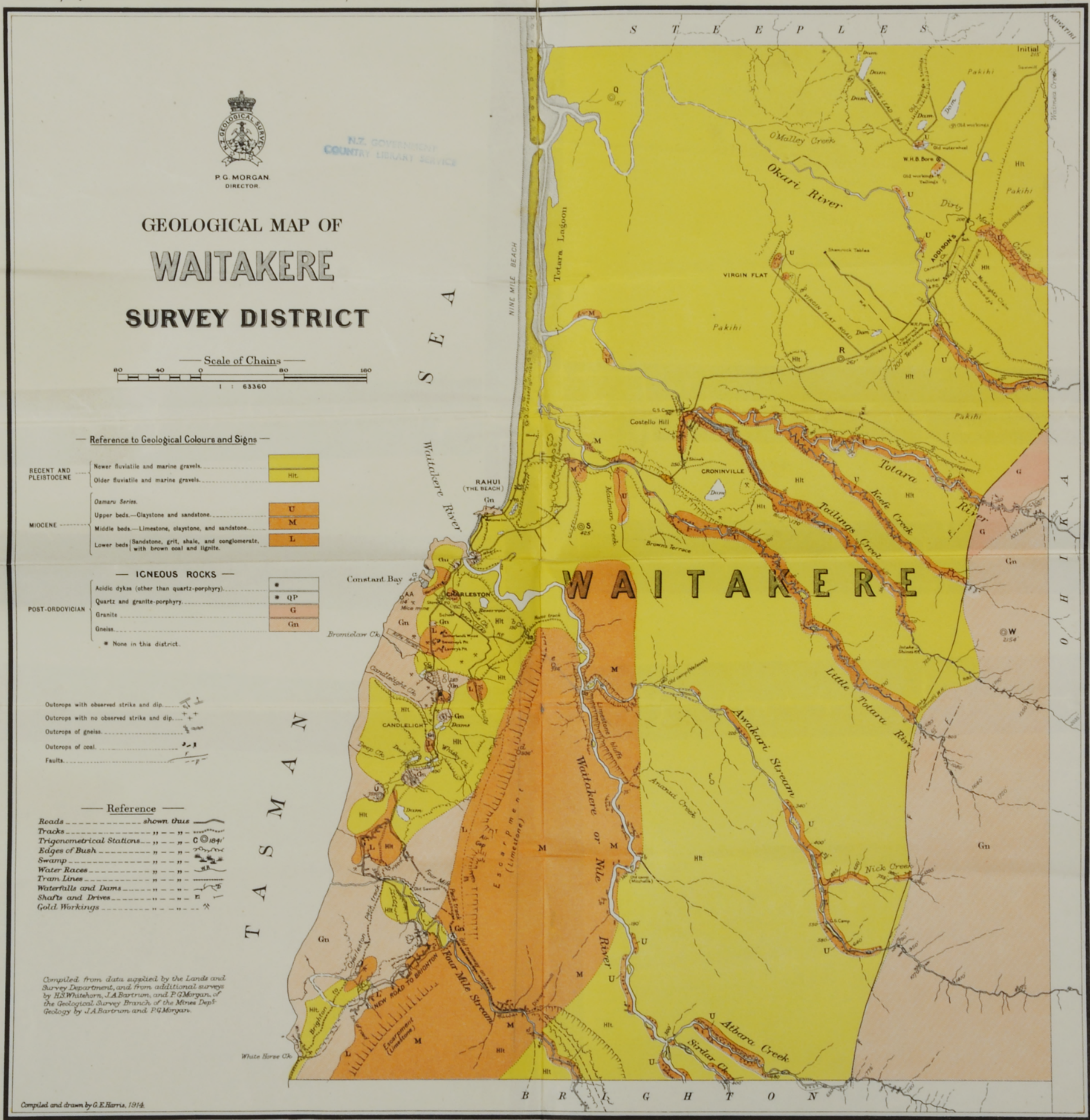
POST-ORDOVICIAN	Basic dykes.	\ B
	Acidic dykes (other than quartz-porphyry).	\ A
	Quartz and granite-porphyry.	QP
	Granite and granodiorite.	
	Minor areas of granite.	G
	Gneiss.	Gn

Areas of coal worked or being worked	
Quartz lodes.	\Q
Barite lodes.	\ Ba
Outcrops with observed strike and dip.	
Outcrops with no observed strike and dip.	+ + +
Outcrops of gneiss.	
Outcrops of coal.	
Faults.	F

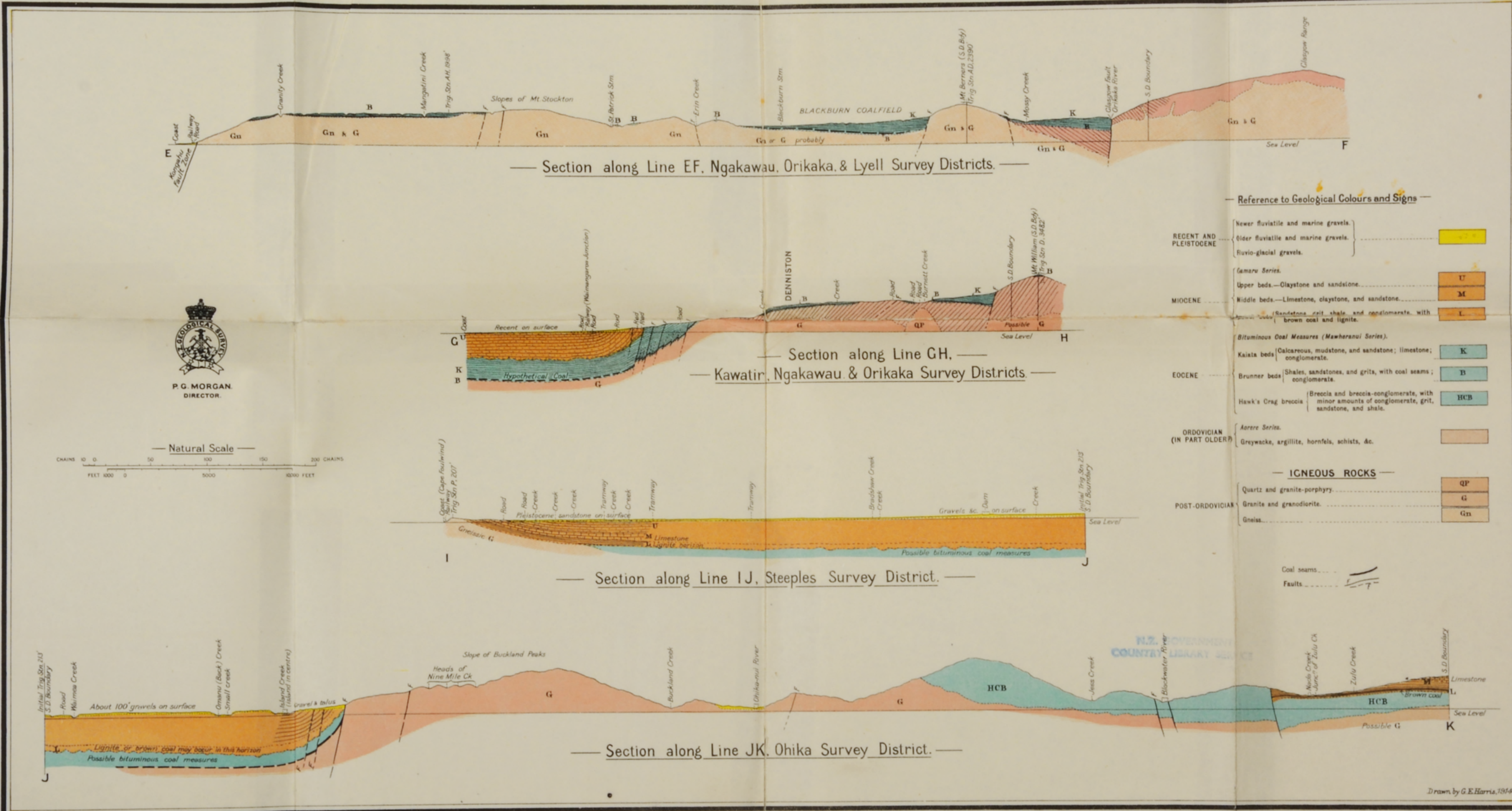
Compiled from data obtained from the Lands and Survey Department, and from additional surveys by P. G. Morgan, J. A. Bartrum & E. S. Whitehorn of the Geological Survey Branch of the Mines Department. Geology by P. G. Morgan & J. A. Bartrum.




MAP OF THE
BULLER-MOKIHINUI SUBDIVISION
SHOWING FAULT-LINES
Scale of Miles
Reference
Proved faults.......................shown thus
Uncertain and hypothetical faults
Dip of faults
Trigonometrical Stations
Survey District names
boundaries
Mokihinui River
MOKIHINUI
Ngakawau River
NGAKAWAU
Glasgow Fault
Waimangaroa River
Buller River
WESTPORT
Cape Foulwind
STEEPLES
KAWATIRI
ORIKAKA
LYELL
WAITAKERE
OHIKA
Papahaua Range
Ohikanui River
Mt. William Range
Waitakere or Nile R.
Fox Ck.
Drawn by G.E.Harris 1914.


N.Z. GEOLOGICAL SURVEY
P. G. MORGAN.
DIRECTOR.
N.Z. GOVERNMENT COUNTRY LIBRARY SERVICE
GEOLOGICAL MAP OF
WAITAKERE
SURVEY DISTRICT
Scale of Chains
80 40 0 80 160
1 : 63360
Reference to Geological Colours and Signs
RECENT AND PLEISTOCENE
Newer fluviatile and marine gravels.
Older fluviatile and marine gravels.
Hlt
MIOCENE
Oamaru Series.
Upper beds.—Claystone and sandstone.
U
Middle beds.—Limestone, claystone, and sandstone.
M
Lower beds. Sandstone, grit, shale, and conglomerate, with brown coal and lignite.
L
IGNEOUS ROCKS
POST-ORDOVICIAN
Acidic dykes (other than quartz-porphyry).
Quartz and granite-porphyry.
QP
Granite
G
Gneiss
Gn
* None in this district.
Outcrops with observed strike and dip.
Outcrops with no observed strike and dip.
Outcrops of gneiss.
Outcrops of coal.
Faults.
Reference
Roads shown thus
Tracks
Trigonometrical Stations
Edges of Bush
Swamp
Water Races
Tram Lines
Waterfalls and Dams
Shafts and Drives
Gold Workings
Compiled from data supplied by the Lands and Survey Department, and from additional surveys by H.S. Whitehorn, J.A. Bartrum, and P.G. Morgan, of the Geological Survey Branch of the Mines Dept. Geology by J.A. Bartrum and P.G. Morgan.
Compiled and drawn by G.E. Harris. 1914.
TASMAN SEA
NINE MILE BEACH
STEEPLES
BRIGHTON
KAHIKATEA
WAITAKERE
Totara Lagoon
O'Malley Creek
Okari River
VIRGIN FLAT
ADDISON'S
Pakihi
Costello Hill
CRONINVILLE
Totara River
Tailings Creek
Little Totara River
Waitakere River
RAHUI (THE BEACH)
Constant Bay
CHARLESTON
Bromielaw Ck.
Candlelight Ck.
CANDLELIGHT
Escarpment (Limestone)
Waitakere or Nile River
Awakari Stream
Nick Creek
Four Mile Stream
NEW ROAD TO BRIGHTON
Atbara Creek
Sirdar Ck.
White Horse Ck.
Brighton
Initial

No. 8


Section along Line EF, Ngakawau, Orikaka, & Lyell Survey Districts.
BLACKBURN COALFIELD
Slopes of Mt Stockton
Granity Creek
Mangatini Creek
St Patrick Stm
Blackburn Stm
Mossy Creek
Glasgow Range
Sea Level
Section along Line GH.
Kawatiri, Ngakawau & Orikaka Survey Districts.
DENNISTON
Recent on surface
Hypothetical Coal
Possible
Sea Level
Section along Line IJ, Steeples Survey District.
Pleistocene: sandstone on surface
Gravels &c. on surface
Limestone
Lignite horizon
Possible bituminous coal measures
Sea Level
Section along Line JK. Ohika Survey District.
Slope of Buckland Peaks
Heads of Nine Mile Ck
About 100' gravels on surface
Gravel & talus
Lignite or brown coal may occur in this horizon
Possible bituminous coal measures
Buckland Creek
Ohika-nui River
Jess Creek
Blackwater River
Zulu Creek
Limestone
Brown coal
Possible G
Sea Level
P. G. MORGAN.
DIRECTOR.
N.Z. GEOLOGICAL SURVEY
Natural Scale
CHAINS 10 0 50 100 150 200 CHAINS
FEET 1000 0 5000 10000 FEET
Reference to Geological Colours and Signs
RECENT AND PLEISTOCENE
Newer fluviatile and marine gravels.
Older fluviatile and marine gravels.
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Upper beds.—Claystone and sandstone. U
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Sandstone, grit, shale, and conglomerate, with brown coal and lignite. L
EOCENE
Bituminous Coal Measures (Mawheranui Series).
Kaiata beds Calcareous, mudstone, and sandstone; limestone; conglomerate. K
Brunner beds Shales, sandstones, and grits, with coal seams; conglomerate. B
Hawk's Crag breccia Breccia and breccia-conglomerate, with minor amounts of conglomerate, grit, sandstone, and shale. HCB
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Aorere Series.
Greywacke, argillite, hornfels, schists, &c.
IGNEOUS ROCKS
POST-ORDOVICIAN
Quartz and granite-porphyry. QP
Granite and granodiorite. G
Gneiss. Gn
Coal seams
Faults
Drawn by G.E.Harris, 1914.

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Dept. of Mines. Geological Survey.

Bulletin 17 (new series)

The Geology and mineral resources of the Buller-Mokihinui Subdivision

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by Morgan, P. G. and Bartrum, J. A.

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