Petroleum.

In west Nelson traces of oil are found at Karamea, Reefton, Dobson, and Kotuku. At Reefton the oil occurs in connection with certain shales underlying the coal. As pointed out by Morgan and Webb,* the source of the oil is undoubtedly the beds of the coal series. At Karamea and Reefton the shales and claystones which carry the oil are upturned by powerful faults, and the structure is synclinal.

At Dobson the bore from which the oil issues penetrates the western limb of the Brunner anticline. Between this bore and the crest of the anticline runs a branch of the great Mount William fault, to the west of which the oil will occur. At Kotuku the oil-permeated gravels lie over the northern continuation of the Ross fault, and it seems feasible to suppose that these supplies of petroleum are soaking up along this fault. The structure of the underlying coal-beds will be monoclinal.

Summary.

(1.) The coals of west Nelson, as first suggested by Professor Park,† have accumulated as marginal (probably drift) deposits.

(2.) The coal-measures belong to one system only, and present an unbroken sequence.

(3.) The more highly carbonized coals are generally the more elevated, or, more exactly, those from above which the impervious strata have been removed wholly or in part. This "stripping" permitted a relatively rapid escape of distillation-products and a relatively rapid distillation of the vegetable matter. It should be noted that Professor Park‡ has long insisted on the influence exercised by the character of the overlying measures in determining the formation of different classes of coal.

(4.) The chances of large supplies of petroleum being found in west Nelson are not good. A certain amount may occur along faults.

Art. XXXVI.—*On the Genesis of the Surface Forms and Present Drainage-systems of West Nelson.*

By J. Henderson, D.Sc., A.O.S.M.

Communicated by Professor James Park.

[*Read before the Otago Institute, 14th September, 1909.*]

The term "west Nelson" as here used includes all that part of the north-west of the South Island which lies to the west of the main divide and north of the Taramakau. This portion of New Zealand has an area of close on 8,000 square miles, and consists of a series of earth-blocks, which at one time presented a comparatively even surface, but which have suffered such a differential elevation that some of the blocks have been raised till their surfaces are 5,000 ft. or more above the surfaces of the other blocks,

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* Morgan: Geol. Surv., 3rd Ann. Rep. (n.s.), pp. 9, 10. Webb: *Idem*, p. 23.
† Park: "Geology of New Zealand," 1910, p. 280 *et seq.*
‡ Park: "Mining Geology," 2nd ed., 1907, p. 32.

forming a group of block mountains analogous to those in Otago,* except that, having been subjected to the more active denudation-conditions obtaining in this portion of New Zealand, they have been more thoroughly dissected. At present only the comparative equality in height of the higher peaks indicates the ancient peneplanation.

FAULTS.

There are, then, two elements in the geography of west Nelson—the peneplains and the rift-valleys—and the limits of both of these are generally determined by powerful faults. There are two groups of normal downthrow faults, separated by the great alpine overthrust, those lying to the west of this overthrust belonging to west Nelson, and those to the east to the alpine range.

The main structural fault of west Nelson, and, indeed, of the South Island, is the great alpine overthrust† which runs from Foveaux Strait to D'Urville Island. This overthrust follows the Gregory Valley of Morgan,‡ which may be traced from Lake Kanieri to Lake Rotoiti.§ Its course has been indicated by Hector‖ and Mackay.¶ On the western side of this great fault have been intruded igneous magmas, which abut at intervals against the overthrust from South Otago to Lake Rotoiti, in Nelson. On both sides of the fault occur basic and ultrabasic intrusions of later age than the granitic intrusions already mentioned. On the east side they occur from D'Urville Island to Otago, forming in part the Pounamu formation of the Geological Survey. On the west side these rocks are represented by lavas at Koiterangi and Paringa, and by dykes at many points.

The faults of the alpine range are exceedingly numerous, and tend to run either north and south or east and west.** They are often indicated by hot hepatic springs, as in valleys of the Maruia, Upper Grey, Hurunui, Trent, and Taipo Rivers. North-and-south faults occur in the Upper Taipo, Otira, Waikite, and Trent. East-and-west lines of faulting—perhaps *blatten*—are followed by the Upper Taramakau and Hurunui, the Waiheke, and Doubtful, the Marchant, Upper Grey, Maruia, and Henry Rivers. The Wairau†† fault is different from the faults of the alpine peneplain, hitherto considered: it has a more easterly trend than either the main alpine overthrust or the great faults of the Kaikouras and North Island ranges—it is, in fact, a connecting-link between these two great parallel systems of breaks.

The faults to the west of the alpine overthrust tend to run in two directions—north and south, and north-east and south-west.‡‡ The first to be considered, the Motueka fault, probably skirts the coast of Tasman Bay, running south from Separation Point to the mouth of the Motueka,

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* Park: N.Z. Geol. Surv. Bull. No. 2 (n.s.), p. 6 *et seq.*; No. 5 (n.s.), p. 6 *et seq.*; "Geology of New Zealand," 1910, p. 11.

† Mackay: Geol. Surv., No. 21, p. 20. Morgan: N.Z. Geol. Surv. Bull. No. 6 (n.s.), p. 71 *et seq.*

‡ Morgan: N.Z. Geol. Surv. Bull. No. 6 (n.s.), p. 38.

§ Haast: Geol. Explor. of West Nelson, p. 94.

‖ Hector: Geol. Surv., No. 4, p. 29.

¶ Mackay: Mines Statement and Goldfields Reports, 1893, pp. 136, 174.

** *Cf.* Morgan: N.Z. Geol. Surv. Bull. No. 6 (n.s.), p. 70.

†† Mackay: Geol. Surv., No. 21, p. 19.

‡‡ Park: Geol. Surv., No. 19, p. 83. Mackay: Geol. Surv., No. 21, pp. 20, 21. Mackay: Geol. Surv., No. 12, pp. 124, 125, 127 (in this and in many following references faulting is not definitely stated, but may be inferred).

where it turns south-west and follows the flanks of the Mount Arthur Range, contorting the strata in the Graham, Baton, and Wangapeka Rivers. One branch runs south-east along the Sherry River,* and probably reaches the alpine overthrust near Lake Rotoiti. The main fault is continued into the basin of the Owen,† which river it follows to the junction of the Mangles, thence crossing to the Matakitaki. The Tutaki† fault leaves the Motueka fault at the Owen, flanks the Murchison peneplain on the west, into the head of the Tutaki, thence by the Glenroy junction along the Warbeck and Warwick Rivers to the Maruia. The Matiri‡ fault, parallel to the Motueka fault, shows itself in the Upper Wangapeka and probably the Upper Crow, follows the Upper Matiri to the Maruia junction, thence by Deepdale into Larry's Creek, and flanks the Victoria peneplain on the west, reaching the alpine overthrust near Lake Haupiri.

The Takaka fault§ follows the Takaka River for twenty miles, thence crosses the range joining the Motueka fault near the Baton. The Karamea fault‖ crosses the Mount Arthur tableland from the Takaka to the Leslie, thence into the Upper Karamea; it determines the course of the north and south branches of the Mokihinui, thence to the Buller by way of New Creek. The Mawhera fault,¶ a direct continuation, flanks the eastern base of the Paparoas, running to sea south of the Taramakau. A subsidiary parallel fault to the west determines the course of the Orikaka and Blackwater Rivers. The Inangahua fault** leaves the Karamea fault at New Creek, flanks the western base of the Brunner Range and the foothills of Victoria Range, reaching as far south as the Big Grey, where its southern continuation is overlain by Old Man gravels. The Ross fault†† is a south-west fault, flanking the western of the granite foothills from the Grey River to Ross; it manifests itself at Koiterangi and Mount Greenland.

The Aorere fault‡‡ runs along the western shores of Golden Bay and follows the Aorere, and thence by way of Brown's Creek across the Gouland Downs. The Wanganui fault runs south-west through West Wanganui Inlet, and a probable parallel fault determines the trend of the coast from Cape Farewell to Rocks Point. The Lower Buller fault§§ follows the coast-line south-west from north of the Mokihinui, and skirts the higher land from the Ngakawhau to the entrance of the Buller Gorge, thence to the coast at the mouth of Fox's River. The Mount William fault‖‖ flanks

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* Mackay: Geol. Surv., No. 12, p. 130.

† Haast: Geol. Explor. of West Nelson, pp. 95, 96. Cox: Geol. Surv., No. 16, pp. 5, 6, 8. Park: Geol. Surv., No. 19, pp. 79, 82, 84.

‡ Hector: Geol. Surv., No. 4, p. 27. Cox: No. 16, p. 6. Park: No. 19, p. 80. Mackay: Geol. S.W. Nelson, pp. 11, 12, 57.

§ Park: Geol. Surv., No. 20, p. 192. Mackay: No. 21, p. 21. Bell: N.Z. Geol. Surv. Bull. No. 3 (n.s.), p. 50.

‖ Hector: Geol. Surv., No. 4, p. 27. Cox: No. 9, p. 117. Mackay: No. 21, p. 21: Mackay here ascribes the dislocation of the rock at the base of the Lyell Mountains and at New Creek to his Motueka fault. Mackay: Geol. S.W. Nelson, p. 12.

¶ Mackay: Geol. Surv., No. 8, pp. 103, 104, 105; No. 21, p. 21 (Motueka fault); Geol. S.W. Nelson, p. 58.

** Mackay: Geol. Surv., No. 15, pp. 145, 146, 147.

†† Bell: N.Z. Geol. Surv. Bull. No. 1 (n.s.), p. 81. Morgan: N.Z. Geol. Surv. Bull. No. 6 (n.s.), pp. 70, 71.

‡‡ Hector: Geol. Surv., No. 4, p. 19. Cox: No. 15, pp. 71, 72. Park: No. 20, p. 202. Bell: N.Z. Geol. Surv. Bull. No. 3 (n.s.), p. 50. Mackay: Papers and Reports, 1896, C.–11, p. 9.

§§ Mackay: Geol. Surv., No. 8, pp. 107, 109, 112; No. 21, pp. 22, 78.

‖‖ Mackay: Geol. Surv., No. 8, pp. 76, 110, 113; No. 21, p. 78; Geol. S.W. Nelson, p. 58. Webb: Geol. Surv., 2nd Ann. Rep. (n.s.), p. 26.

the granite ranges south from Mount Domett, enters the Mokihinui basin by Rough-and-Tumble Creek, thence along the Upper Ngakawhau and Waimangaroa, past Mount William, and across the Buller by way of Cascade Creek; thence it flanks the Paparoa peneplain to Point Elizabeth: a branch probably crosses the Grey between the first and second gorges.

The faults of west Nelson, as far as the writer can tell, are all distributed faults, often many chains wide.

PENEPLAINS.

The fractures of which the general course has just been indicated separate the two main elements in the geography of the area, the peneplains and areas of depression.

The most northerly elevated earth-block is that forming the Whakamarama Range. This peneplain has a north-east and south-west extension, and is bounded by the Aorere and Wanganui faults. The highest peak is 3,980 ft., and several peaks attain 3,500 ft. This block consists mainly of Palaeozoic rocks with a north and south or north-north-east and south-south-west strike.* It is skirted on the west by a belt of Tertiaries, and is overlain on its northern limb by the same rocks.†

The Pikikiruna peneplain is bounded by the Motueka and Takaka faults. The highest peak is 4,359 ft., and the average of five peaks is 3,920 ft. The slope is to the north half of this earth-block, to the north and east is of granite, the rest of Palaeozoic rocks,† the strike of which varies much from north-east and south-west to north and south.‡

The Mount Arthur peneplain is the principal one in this part of the country. From it have been carved the Mount Arthur, Douglas, Haupiri, Anatoki, and Leslie Ranges. It is limited by the Takaka and Motueka faults on the east; on the west by the Aorere fault and by a probable continuation of the Mount William fault. It is separated from the Lyell peneplain on the south by the saddle between the Baton and Karamea. This depression may be a fault-rift, or it may be a col between the truncated domes (uplifted by the laccolites beneath) of the Mount Arthur and Lyell peneplains. The Mount Arthur peneplain is traversed by the Karamea fault, which cuts off the Mount Arthur Range from the rest of the peneplain. The highest point is 6,000 ft. above sea-level, and the mean of eleven peaks is 5,110 ft. Granites appear right along the eastern and western borders of this earth-block, and in patches in the north; in fact, the Palaeozoic sediments which form the central portions rest on a vast plinth of granite.§ These sediments contain numerous dykes, and strike from north-west and south-east to north-north-east and south-south-west.‖

The Lyell peneplain is determined on the east by the Motueka fault, on the west by the Mount William fault, on the north by the col beforementioned, and on the south by the Upper Buller Gorge, which the Buller has formed by cutting through the saddle between the Lyell and Victoria peneplains. The Karamea and Matiri faults traverse this peneplain. The

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* Cox: Geol. Surv., No. 15, p. 66.

† Park: Geol. Surv., No. 20, p. 186 *et seq.*

‡ Cox: Geol. Surv., No. 13, p. 2. Park: No. 20, p. 228. Hochstetter's "New-Zealand," p. 102.

§ Mackay: Geol. Surv., No. 12, pp. 102, 122. Cox: No. 14, pp. 43, 44; No. 15, pp. 63, 64. Park: No. 20, pp. 230, 231. Bell: N.Z. Geol. Surv. Bull. No. 3 (n.s.), p. 70 *et seq.*

‖ Mackay: Geol. Surv., No. 12, pp. 125, 127, 128. Cox: No. 14, pp. 45, 49, 50, 51 Park: No. 20, pp. 210, 211, 213, &c. Bell: N.Z. Geol. Surv. Bull. No. 3 (n.s.), pp. 34, 45.

highest peak is 5,750 ft., and the mean of twenty peaks is 4,800 ft. In structure the Lyell peneplain resembles the Mount Arthur peneplain, the ancient sediments, and in part also Cainozoic rocks resting on a platform of granite. Thus on the west the peneplain is edged by the granites of Mount Radiant and Mount Glasgow, and granites occur on the south and east.* The strike of the older sediments is nearly north and south.†

The Murchison peneplain is separated from the Lyell peneplain by the Motueka fault. It is determined on the west by the Tutaki fault, on the south-east by the alpine overthrust, and on the east by the Sherry fault. The highest peak is 4,629 ft., and the mean of eight peaks is 4,000 ft. This block is low on the east, due to denudation and to the overriding of the alpine peneplain. It has been very thoroughly dissected, so that only on the west do sediments which strike north and south occur.‡ To the east the granite has been cut out into isolated pyramids.

The Victoria peneplain, the remnants of other domes, is bounded by the alpine-overthrust and Matiri faults. The Matiri fault traverses its northern end, and roughly separates the Brunner and Victoria Ranges. The highest peak is 5,571 ft., and the mean of twenty peaks is 4,930 ft. Denudation has removed nearly all the sediments first uplifted by the laccolites. A strip of slate with a north-and-south strike§ borders its western flank. Patches of Cainozoic rocks occur on the west and north-east.

The Wainihinihi peneplain‖ flanks the alpine divide as far north as Bell Hill. The alpine overthrust separates it from the alpine peneplain, and on the west it is determined by the Ross fault. This peneplain, which has a north-east and south-west extension, has been very thoroughly dissected by rivers flowing across it from the alpine peneplain. It now consists of a series of pyramidal peaks with an average height of, say, 4,000 ft. The sediments which formed part of its original mass occur only as narrow strips flanking the west of the peaks from Bell Hill to Ross, and striking north-north-east to north-west.¶

The Paparoa peneplain is a truncated dome the sediments of which flanked it before peneplanation; elevation and faulting are now represented by the slates at its northern and southern extremities, which strike from north-west to north-east.** It is bounded by the Mawhera and Lower Buller faults. Its highest peak is 4,250 ft., and the mean of five peaks is 4,000 ft. This peneplain is almost entirely surrounded by Cainozoic rocks derived from its own degradation.††

The alpine peneplain is of the same age as the other peneplains of the area. It stretches without break from D'Urville Island to Otago.

The wonderfully well-preserved groups of block mountains occupying Central and North Otago, first described by Professor Park,‡‡ are the

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* Haast: Geol. Explor. of W. Nelson, pp. 98, 99. Mackay: Geol. S.W. Nelson, p. 66. Webb: Geol. Surv., 2nd Ann. Rep., pp. 26, 27.

† Park: Geol. Surv., No. 19, pp. 81, 82. Webb: *Loc. cit.*, p. 27.

‡ Park: *Loc. cit.*, pp. 81, 82.

§ Haast: Geol. Explor. of W. Nelson, p. 101. Mackay: Geol. Surv., No. 15, p. 123 *et seq.*

‖ Bell: N.Z. Geol. Surv. Bull. No. 1 (n.s.), p. 26.

¶ Bell: *Loc. cit.*, p. 46. Morgan: *Ibid.*, No. 6 (n.s.), p. 97.

** Cox: Geol. Surv., No. 9, p. 76.

†† Mackay: Map with Geology of S.W. Nelson.

‡‡ Park: N.Z. Geol. Surv. Bull. Nos. 2 and 5 (n.s.), 1906, 1908; and "Geology of New Zealand," 1910, pp. 10, 11, 144.

remains of the Otago peneplain, which is merely the southern continuation of the alpine peneplain of Canterbury and Westland.

On the west the alpine peneplain is bounded throughout its entire extent by the great alpine overthrust. It occupies a great part of Marlborough, east Nelson, and Canterbury. Like the other peneplains, it has been subjected to differential uplift, and, on the whole, the uplift has been greater. From the head of the Taramakau to the head of the Maruia the average height of the peaks is about 6,000 ft.; from Cannibal Gorge to Lake Rotoiti the mean is well over 7,000 ft.; while north of Lake Rotoiti few of the summits overtop 5,000 ft., and going north the height sinks gradually to 2,000 ft. on D'Urville Island.

THE AREAS OF DEPRESSION.

The first of these to be considered, the Taitapu depression, is at present occupied to a great extent by Golden Bay. It is bounded on the west by the Aorere fault, and on the south by a probable fault parallel and subsidiary to the Cook Strait fault, which passes north of Cape Farewell. Two arms of this depression extend southward along the rift-valleys of the Aorere and Takaka. These two prolongations are filled with three series of deposits. The oldest of these deposits consists of conglomerates, sandstones, and limestones of probable Miocene age; the next deposit consists of gravels, and mudstones laid down when the land stood at a lower level —probable age Pleistocene; the other series of deposits are the gravels of Recent age.

The Whakatu rift-valley is bounded by the Motueka, Sherry, and alpine-overthrust faults. Its northern depressed end is occupied by Tasman and Blind Bays. The southern end is occupied by a vast deposit of gravels —the Moutere gravels—of Pleistocene age. On the south these gravels cover—in fact, completely cross at one point—the Murchison peneplain. At numerous points around the edges of the valley the Miocene coal-measures outcrop, and it seems reasonable to suppose they form the floor of the whole valley.

The Kawatiri rift-valley, separated from the Whakatu Valley by the Murchison peneplain, is bounded by the Tutaki, Matiri, and alpine-overthrust faults. It lies at a higher level than the areas of depression hitherto described, and is occupied chiefly by the Miocene rocks, the Pleistocene gravels which may at one time have covered the coal-measures having been almost entirely removed.

The Oweka depression (named from the Maori name for the plains of the Inangahua*) lies between the Victoria and Paparoa peneplains, and extends northward into the valley of the Orikaka, and perhaps into the basin of the Mokihinui. It is bounded by the Mawhera, Inangahua, and Ross faults. Like the other rift-valleys, its floor is covered with Miocene strata, which in turn are overlaid by Pleistocene (Old Man) gravels and Recent river-wash.

A long depressed strip faces the Tasman Sea, in places sinking in steps from the Paparoa, Lyell, and Mount Arthur peneplains, which bound it on the east. In this coastal strip occur the basement rocks, granite, greywacke, the Miocene coal series, Pleistocene and Recent gravels.

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* Haast: Geol. Explor. of W. Nelson, p. 76.

Geological History.

A tentative account of the later geological history of west Nelson is here put forward. In Mesozoic times what is now New Zealand formed the littoral of the primary coast of the Pacific Ocean. The vast accumulation of sediment which seems to precede the formation of fold-mountains was deposited. Then a fold-movement was initiated, probably contemporaneous with the sinking of the land now occupied by the Tasman Sea. This folding ridged the land into a series of folds running north-north-east and south-south-west to north-west and south-east, or, say, on an average north and south.* Then, probably in late Mesozoic or early Cainozoic times, the alpine orogenic folding commenced, which culminated in the production of the great alpine overthrust. This crosses the older north-and-south folds obliquely, running as it does north-east and south-west parallel to the alpine folds. The pressure forced molten magmas† into the rocks along the lines of weakness. Of these lines of weakness the principal is the alpine overthrust, and granites occur just to the west of this line in west Otago and from Mount Bonar in Westland to Lake Rotoiti in Nelson. Besides the granites immediately abutting on the alpine overthrust, the intense pressure from the east forced up magmas along lines of weakness farther to the west. Thus great laccolites occur along the axes of the older north-and-south folding. In west Nelson the longer diameter of the granites of the Murchison peneplain are continued north-north-east and north to Separation Point, and the granites of Victoria peneplain trend north and south, and their northern end is very close to and perhaps continuous with the granites flanking the west of the Lyell and Mount Arthur peneplains. These north-north-east and south-south-west lines of weakness continued northward pass through Taranaki and the Auckland Peninsula, while the alpine-overthrust line passes near Taupo and White Island. It is probable that even at this period the great fracture-lines had been initiated,‡ the breaks running north and south or north-east and south-west, according as the influence of the north-and-south folding or the pressure from the south-east predominated. At already pointed out, the faults of the alpine peneplain strike nearly either north and south or east and west, while the overthrust strikes north-east and south-west. It is suggested that the north-and-south faults follow lines of weakness developed by the old north-and-south folding, while the east-and-west faults represent the breaking-back of the fissures to the line of greatest tension.

The land seems to have been above sea-level till Tertiary times, when depression permitted the inroads of the sea into the rift-valleys which had already been formed. Deposits accumulated in these rift-valleys. In ascending order, they are conglomerates, sandstones, and shales with coal-seams; then mudstones and dark strata, analogous to those at present forming on the shores of Blind and Golden Bays, West Wanganui Inlet, Otago Harbour, and, indeed, any land-locked arm of the sea silting up. Further depression permitted the formation of sandstones, calcareous sandstones, arenaceous limestones, and finally pure shelly limestones. When these last were formed the land-surface of what is now west Nelson was

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* *Cf.* Morgan: N.Z. Geol. Surv. Bull., No. 6 (n.s.), p. 78. Dobson (quoted by Hochstetter, "New Zealand," p. 485) states that the strike of the beds is north-east, while the general trend of the range is north-east.

† The granites of west Nelson are not at all the same age.

‡ The numerous lodes of west Nelson occur near the great faults.

represented by a series of base-levelled islands; to the east the long line of what is now the alpine peneplain rose from a shallow sea.

Elevation now took place. In this portion of New Zealand the elevation was of the plateau-forming order, merging into the fold-movement of the Kaikouras and North Island ranges. This fold-movement was accompanied, perhaps casually, by the foundering of the northern continuation of the alpine peneplain. The elevation was accompanied in west Nelson by the intrusion of the unconsolidated ultrabasic portions of the magmas, of which the acid portions are represented by the granites that even in Miocene times had been exposed by denudation. The lavas of Koiterangi and Paringa and the dunites of the Pounamu formation belong to this period. Here also belong the protogines and hornblende granulites produced by movement along the alpine overthrust. The elevation was of a differential nature, and the alpine peneplain was elevated more than the other peneplains. Again, different parts of the alpine peneplain were differentially elevated, and the greatest elevations seem to be immediately opposite to the depressions on the west of the overthrust. Thus in Westland, south of the Wanganui, the alpine peneplain has been very greatly elevated, while the granites which probably at one time occurred here to the west of the overthrust have disappeared. Again, the alpine peneplain is relatively high between the Upper Maruia and the Wairau, and to the west of the overthrust is the Kawatiri depression. Opposed to the Whakatu rift-valley and the relatively depressed alpine peneplain is the high land of the Kaikouras.

DRAINAGE.

The elevation of late Miocene times initiated a new cycle of erosion. The streams from the base-levelled land united to form larger streams, which flowed through the rift-valleys across the newly deposited strata. Thus the Aorere was formed from streams draining the west and north-west of the Mount Arthur peneplain. The Whakamarama peneplain on elevation was tilted to the north and west, and the consequent streams flow north-west to the sea; later, the Kaituna broke through the eastern fault-scarp and captured some of this drainage for the Aorere, which, however, lost its head-waters to the Heaphy and Big Rivers.* The Takaka cut out its channel along the Takaka and Karamea faults as far as the Upper Karamea,† which was afterwards captured by the Karamea in accordance with the law of greatest slopes. The Kawatiri basin at this time drained into the Whakatu,‡ while the Oweka rift-valley was drained by a river having the head-waters of the Mokihinui as its course, and its mouth near Lake Brunner.§ Tributaries from the alpine peneplain flowed right across the intervening Victoria peneplain: such were the Ahaura, Upper Grey, and Inangahua, the volume of the latter being then increased by the present Upper Maruia. Similarly, the Taramakau flowed across the Wainihinihi peneplain.

A pause in elevation permitted the river-systems to mature and a vast accumulation of gravels to be formed. These gravels occur in the valleys of the Aorere and Takaka. The Whakatu filled its valley with the Moutere

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* Cox: Geol. Surv., No. 16, p. 67.
† Mackay: Gold-deposits of N.Z., p. 11.
‡ Cox: Geol. Surv., No. 16, p. 68. Park: Trans. N.Z. Inst., vol. 37, p. 549.
§ Haast: Geol. Explor. of W. Nelson, p. 103. Marshall: Geog. of N.Z., pp. 140, 141.

gravels, which reach a height of 3,000 ft. above sea-level and overlap the Murchison peneplain right to the Kawatiri basin. The Oweka Valley was filled by the gravels of the Old Man Bottom, which as they were pushed farther and farther south overlaid the beds known as the Blue Bottom. These are practically contemporaneous with the Old Man Bottom beds, and were laid down in a shallow bay, to be ultimately covered by the advancing delta of the Oweka and other lesser streams from the alpine peneplain.

Further elevation now took place, and the present cycle of erosion commenced. The peneplains, lifted more rapidly than the rift-valleys, were now sufficiently high to allow vast snowfields and glaciers to form. They were not at that time so thoroughly dissected as at present, and the surface of high land was much greater than now. The Mount Arthur, Lyell, Victoria, and Paparoa peneplains all testify to the former existence of glaciers, and the alpine peneplain shows traces of a much more extensive glaciation than now obtaining. This elevation brought about many changes in the river-systems. The Wairau, eating back along the great Wairau fault, captured the head of the Motueka.* The Oweka had formed a coastal plain, and its mouth had been forced to the north by the prevailing northerly drift. When elevation took place it was handicapped in cutting back by the hard Miocene sandstone immediately underlying the alluvium of its lower course Moreover, the eroding-power near its mouth was greatly lessened by the deposition of the great bulk of the sediment in its sluggish middle course. The Mokihinui and Buller, small consequent streams, broke into and captured the upper portion of the Oweka. The Mokihinui had only the rock-bound source of the Oweka, but the Buller reached the unconsolidated Old Man gravels, and carved its way south, capturing the Inangahua,† which had already been beheaded by the Upper Grey. The stream which cut the Upper Buller Gorge had now a greatly augmented eroding-power, and captured the drainage of the Kawatiri basin, the outlet to the Wairau being blocked by the great glaciers which formed Lakes Rotoroa and Rotoiti. The conquest of this basin was contemplated when the head of the Maruia was transferred from the Upper Grey.‡ This must have taken place almost within historic times.

At one time, also, the streams forming the Grey formed a river flowing to the east of its present course. A range of Old Man Bottom hills lies between this old course and the present course of the Grey.

Summary.

(1.) West Nelson consists of a series of earth-blocks differentially elevated.

(2.) The fault-lines separating the blocks were probably established at the time of the intrusion of the granites, consequent on the orogenic movement which formed the alpine chain.

(3.) The first cycle of erosion, which was very complete, produced the coal series and base-levelled the elevated earth-blocks. The radial drainage obtaining on the western portion of the Mount Arthur peneplain and on the Pikikiruna, Lyell, and Paparoa penplains has probably been evolved from this ancient drainage.

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* Haast: Geol. Explor. of W. Nelson, pp. 3, 90, 91.
† Haast: *Loc. cit.*, p. 103. Marshall: Geog. of N.Z., pp. 140, 141.
‡ Mackay: Geol. of S.W. Nelson, p. 43. Mines Statement, 1893, p. 175.

(4.) The second cycle of erosion, though less complete than the first, produced the fluvio-glacial Moutere drifts and the Old Man Bottom gravels, and was initiated by the forcing-up of the peneplains and the consequent reopening of the fractures. The Whakamarama peneplain was tilted to the north-west and the Victoria peneplain to the west, and to this is due their present drainage. The higher elevation of the alpine peneplain caused its western drainage to cross the Wainihinihi, Victoria, and Murchison peneplains where these abut against the alpine peneplain. The drainage of the lower country, which dates back to this time, has been most profoundly influenced by the great fracture-lines, especially in the alpine peneplain.

(5.) The third, or present, cycle of erosion is very incomplete. Further movement took place along the fracture-lines, and certain changes in the drainage.

ART. XXXVII.—*The Mount Arrowsmith District: a Study in Physiography and Plant Ecology.*

By R. SPEIGHT, M.A., M.Sc., F.G.S.; L. COCKAYNE, Ph.D., F.L.S.; and R. M. LAING, M.A., B.Sc.

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