# An Eroded Coastline

By R. Speight

[*Read before the Canterbury Branch, May 5, 1948; received by Editor, June 3, 1948; issued separately, February, 1950.*]

Contents



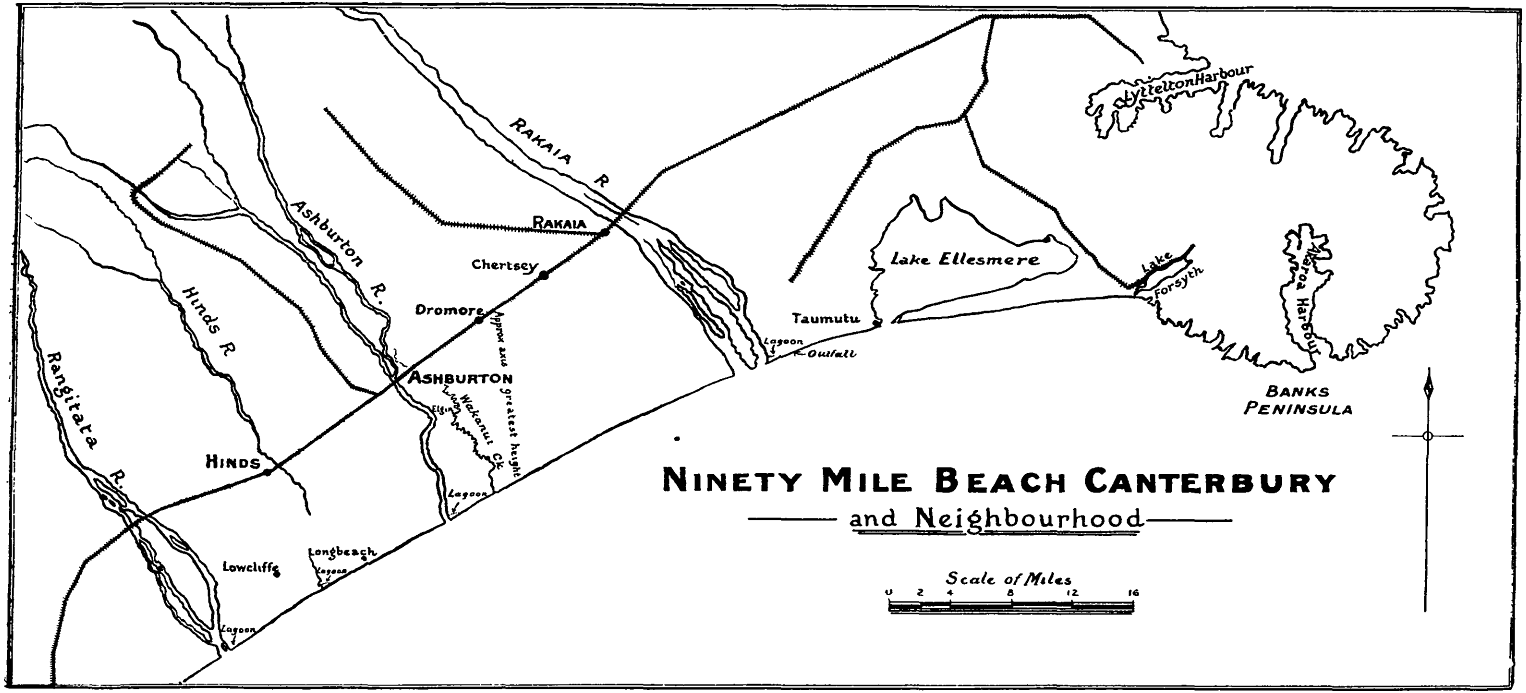
## I. Introduction

That section of the Ninety Mile Beach, Canterbury, stretching from the outlet of Lake Ellesmere at Taumutu to the mouth of the Rangitata River, a distance of some forty miles, has received little attention since it was referred to by Haast (1879, pp. 399–401) in his account of the mode of formation of the Canterbury Plains. This neglect can be understood, since it lies well away from the ordinary run of traffic and has no outstanding features to attract attention. Those who have seen the seaward margin of their land gradually disappear before the assaults of southerly gales seem to be the only people who have taken an interest in it.

The stretch of coastline considered in this account is almost straight, entirely without indentation except for lagoons at river mouths, and dominated by cliffs of sandy gravels incompetent to resist erosion. They are generally vertical, with a beach at their base composed of gravels derived from the cliffs themselves, but with important contributions from existing rivers discharging on the coast. They range from zero to about seventy feet in height. Owing to the difficulty of obtaining a fixed datum level in their vicinity the heights mentioned hereafter are only approximate and obtained by means of an Abney level.

## 2. Canterbury Plains Between the Rakaia and Rangitata Rivers

After these introductory remarks attention may be given to the more or less external factors which have influenced the circumstances of the shoreline, and the first of these is the mode of construction of the Canterbury Plains in the vicinity of the area under consideration. These have been formed from the deposits of streams issuing from the mountain area of the province, chiefly the Rakaia, Ashburton, and Rangitata. It is very likely that these deposits rest upon an older series of more oxidised gravels, perhaps the equivalent of the Kowai




The map shows the location of the places near the coast mentioned in the text. It has not been found possible to reproduce the map showing contour lines as issued by the Department of Lands and Survey.

Gravels. It is usually assumed that the plains were constructed during the Pleistocene and post-Pleistocene glacial period, but by far the greater part had been laid down before the last appearance of the glaciers on their western margin, since morainic material covers the gravels for some distance below the gorges through which the glaciers passed to deploy on the plains (Speight, 1941, pp. 171–2), and no signs of similar deposits can be observed in the underlying layers, exposed in the deeply cut banks of the main rivers, with the possible occurrence of glacial silts in the Rakaia at the gorge, which would indicate the former presence of ice in the locality. This does not mean that the plains were formed before the glacial period, but only before the time when the glaciers reached the western margin of the plains. This event represents the maximum advance, but other maxima with intervening minima no doubt took place earlier, and during that time the plains were built up substantially. Any modification after the retreat of the ice cannot have been considerable, except for the fact that the streams deeply incised their channels in the surface left when the ice retreated.

One point should be mentioned when the relations of the glaciers to the plain deposits are being considered, viz., that the volume of the Ashburton as compared with both the other main streams was formerly relatively greater than that existing at present; this statement does not mean that it was *actually* greater. During the last glacier maximum the Ashburton received a considerable amount of water from the upper reaches of the Rakaia by means of a distributary which left the parent stream above Double Hill, well within the mountain area, passed up the valley now occupied by the Lower Cameron, Lake Stream and Lake Heron—all now discharging to the Rakaia—and joined the main Ashburton just above its lower gorge. It also received a contribution from the Rangitata, for a distributary therefrom passed over the lower course of the Potts River, and joined the Ashburton above its lower gorge at approximately the same place where the distributary from the Rakaia came in. A portion of the overflow from the Rangitata went down the Puddingstone Valley and joined the Rangitata again just above its gorge. The Ashburton did not receive any benefit from this last, but the adventitious supply just indicated certainly increased the amount of water and also of waste beyond what it might have normally received from its own basin. But even this increase would not have raised the level of the Ashburton as a river or waste carrier to that of the Rakaia or Rangitata, as these reached back to the main divide and drained considerably more of the high country apart from the divide than could have been drained by the Ashburton. However, the river with its increased size at this stage must have exerted a substantial influence not only on the building of the plains but also on their final shape.

The form of the present general surface can be clearly seen by examining the contoured maps of the area recently issued by the Department of Lands and Survey. From them it appears that the northern part of the area has been dominated by the Rakaia, while the Rangitata occupies a similar position with regard to the south. Both of these streams have cut deep into the general level of the plains in the upper part of their course. Between them lies the Ashburton, which has not cut down deeply in its upper portion and now lies in a somewhat open trench till it approaches the sea, where it has cut down deeply into the basement beds.

The entrenchment of the Rakaia in the plain gets less and less as the sea is approached. Also the contours show that the axis of highest level of the plain as it is followed seaward does not lie along the course of the stream, but is oriented in a N.W.-S.E. direction from the gorge, so that it crosses the Main South Railway between Dromore and Chertsey, the former ten miles and the latter seven miles south-west of the point where the railway crosses the river The two places just mentioned are practically on the 400 ft. contour line. The bulge which marks the contours as they are followed seaward continues right to the coast, which it reaches north of the mouth of the Ashburton River and near the Wakanui Creek. Allowing that the cliffs here are seventy feet high, the inclination of the surface of the plain from Chertsey to their summit, a distance of twelve miles, is twenty-six feet to the mile. The general position is that the Rakaia has run along the crest of its fan for some distance, is deflected therefrom, and the effect becomes more pronounced as the coast is approached.

The deflection from the crest of the Rakaia fan—or as he called it, the Ashburton fan—has been noted by Hilgendorf (1907, p. 210), when he suggested that the rotation of the earth might account for anomalies in the directions of the Canterbury rivers in their course from the base of the mountains to the sea. He relies on the *average* steepness of the banks of the rivers to prove his case, the steeper bank indicating the direction of deflection. In the case of the Rakaia he notes that points on the southern bank are higher than those immediately opposite on the northern side—according to his criterion a proof that the river is being deflected towards the south; but this is contrary to the direction the river should take if the deflection were due to the earth's rotation. The *average* steeper northern bank of the Rangitata he considered proof that it was moving north—the correct direction if deflection were due to the earth's rotation. It is only fair to say that Hilgendorf was conscious of the discrepancy.

While admitting that rotation of the earth is a *causa vera,* which must be considered when accounting for the deflection of rivers, it frequently happens that some other accidental influence has caused a stream to depart from the crest of its fan and occupy an apparently anomalous position.

Numerous instances can be observed in the mountain regions where the Canterbury rivers rise. It seems to me that a dominating external influence in the case of the Rakaia has been the sinking of the land to the north, and that the area of depression extended on to the northern flank of the fan. There is definite evidence of a recent lowering of the land both north and south of Banks Peninsula, and this is likely to be a more potent influence than the earth's rotation. The question of the level of the land at the mouth of the river will be referred to later.

The greater height of the middle area of the plains between the Rakaia and Ashburton prompted Haast (1879, p. 299) to suggest that this higher portion was formed by the coalescence of the fans of the three main rivers. There are no facts that I am aware of that support this idea, *assuming that the contour maps are correct.* Even with the augmentation mentioned previously, the Ashburton was a much smaller river than the Rakaia, and it now lies in a very shallow trough between the Rakaia and Rangitata. The threshhold where it issues from the mountain area is not as high as that of the Rakaia, so that its grade conferred no advantage on the river as a waste-carrier. There may have been some coalescence or overlapping in the early and middle stages of construction, but I cannot see evidence of such action at a later date. The banks of the Hinds lie at a generally higher level than those of the Ashburton in its upper and middle reaches. Only in its lower reaches does it lie in the hollow between the fans, and at its mouth it lies on the southern slope of the Ashburton fan. The Rangitata runs along the crest of its fan except near the mouth, and even this discrepancy may be due to the marked erosion of the southern bank as suggested by Hilgendorf. If any coalescence of the fans of the three main streams took place when they had reached maturity, the junction lies off the present coastline and has been removed by the sea.

Special attention has been paid to the mode of construction and the form of the plains since the coastal cliff, to be referred to frequently later on, owes many of its features directly to the structure and form of the plains, especially its changing height, and, of course, its lithological composition. This cliff gives a cross-section right along their front, and its varying height is directly dependent on the form of the plains in its vicinity.

## 3. THE COASTAL FEATURES

### I. *North of the Rakaia*

After this preliminary statement of the general situation the actual circumstances of the shoreline may be considered commencing at the Rakaia end. The coastal cliff at the mouth of the river is about twelve feet high—a bank rather than a cliff (Plate , Fig. 2)—but if followed along in a northerly direction it gradually declines in height and finally fades out; in fact, it becomes a negative quantity. The margin of the land is low-lying, very slightly inclined, and if the inclination of the grassed surface is prolonged seaward, it will pass beneath present sea-level at the shoreline. However, it is protected by a continuous shingle beach (Plate , Fig. 1) which rises above the shoreward edge of the plain, the angle of the lower portion of the seaward face being from five to six degrees, the upper part fifteen degrees, while the reverse slope is about six degrees. The feature takes the form of a barrage creeping forward slowly over the low-lying ground on the landward side. Behind it the drainage of the plain formerly found its way parallel to the shore and discharged into the northern end of the lagoon at the mouth of the Rakaia River (Fig. 2) as a stream known as the Little Rakaia. This was sufficiently large to require bridges at the road crossings. The stream has now been diverted direct to sea by means of a culvert through the bank at a point about two miles north of the main river, and the old bed is now almost dry, and being filled gradually by the advancing beach. Near the culvert masses of peaty material, two to three feet in length, are cast up occasionally on the beach and washed down the reverse slope.

These are evidently derived from a swamp deposit in position on the submerged seaward extension of the plain beneath the beach and within the range of erosion by the waves. Other similar outfalls for the drainage occur further north in the direction of Taumutu.

These facts clearly indicate a lowering of this stretch of coastline, which may be part of the extended movement of depression referred to earlier, but it must be remembered that, extending west from Taumutu some six miles to the north, there is a clearly defined old barrier beach, whose crest is now about twenty-five feet above present sea-level (Speight, 1930, p. 163). This clearly indicates that the land was formerly lower than at present, and that it is passing through a period of instability.

A depression similar to that just mentioned occurs at the southern end of the plains as indicated by the drowned valleys and submerged forests near Timaru, and this instability at both ends of the beach under consideration suggests a possible explanation of the present higher level of the central portion, viz., that the northern and southern ends have been lowered while the central portion has remained stable or actually have been warped upwards, the axis of the anticline so formed corresponding with the ridge of higher land passing south-east through Dromore-Chertsey as mentioned earlier. The faults and fault-traces, some oriented on N.W.–S.E. lines involving recent gravels which occur in the mountain area in the vicinity, indicate some crustal instability. However, the only feature of the area adjacent to the coastline which might support such an hypothesis is the existence of high river terraces at the mouths of the Wakanui and Ashburton, and their decline in height upstream. This can be explained most satisfactorily by the rapid marine erosion of the incompetent beds and the consequent adjustment of the grade of the rivers near the coast. The absence of coastline evidence discounts the hypothesis.

Mention should be made in this connection of the marked recent erosion of the New Brighton sand-spit on the north side of Banks Peninsula. This erosion seems to be related in some way to a possible depression of the land, although tidal records at the adjacent port of Lyttelton do not support the contention. However, the flooded lower course of streams like the Avon and Heathcote discharging into Sumner Estuary do give some evidence for such a movement—evidence which is masked on reaches of the sea-shore near the Waimakariri mouth by material poured in by that river and deposited on the sea-bed by a southward-moving current, which becomes progressively less and less effective as the distance from the river-mouth increases. Thus the end of the spit receives no such addition and erosion is not checked or masked.

II. *Rakaia to Ashburton River*

South of the Rakaia the coastline is marked by a definite cliff, usually vertical or nearly so, formed of loosely consolidated gravel and sand, and therefore incompetent to resist attack from the sea. At a point two and a-half miles south of the river mouth it is twenty feet in height, and when followed south it gradually increases with increase in the height of the surface of the plain, till at the mouth of the Ashburton it is nearly seventy feet in height (Plate , Figs. 3 and 4). The country south of the Rakaia is relatively dry; streams

FIG. 1—Shore two miles north of Rakaia Mouth, showing beach advancing over edge of the plain; view looking south.

FIG. 2—Mouth of Rakaia, looking north, showing lagoon, with low cliff in middle distance on left; barrier beach on right.

*To face page* 8].

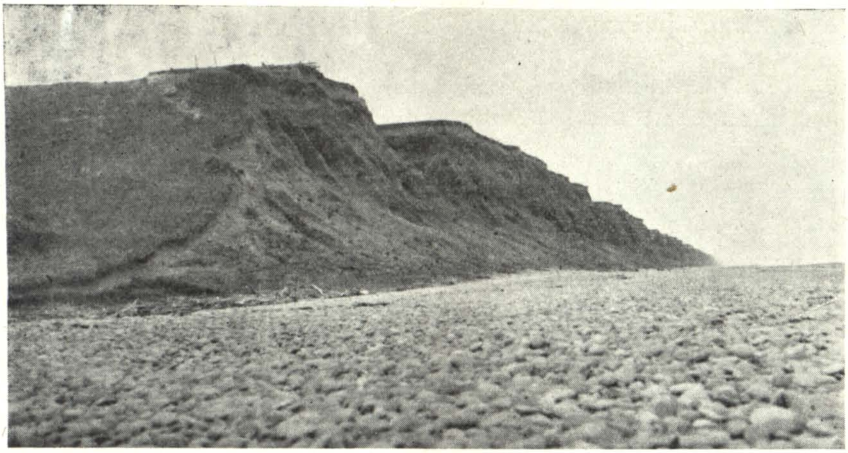


FIG. 3—Cliff on north side of Wakanui Creek, view looking north; gravel beach piled against base of cliff.

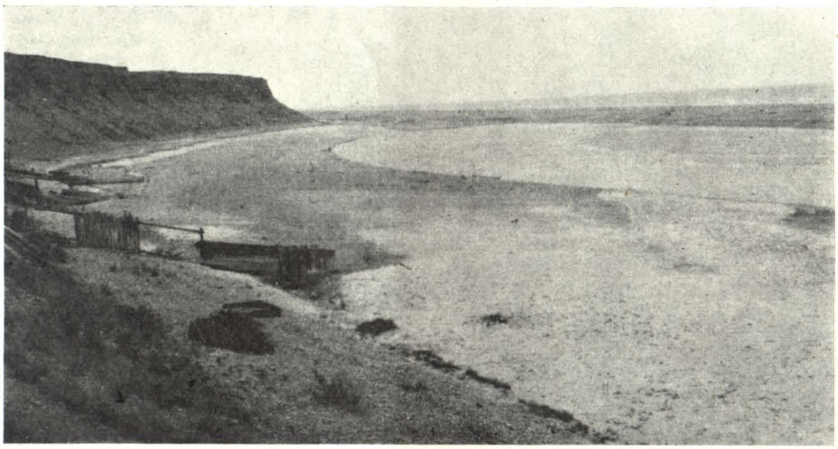


FIG. 4—Mouth of Ashburton River at seaside resort, view looking north; eroded cliff on the left, with beach, in front of this the lagoon, and barrier beach on the right.

FIG. 5—Cliff on south side of Ashburton River, view looking south; gravel beach piled against the base.

are rare, but the cliff is cut in places by short gullies carrying no permanent water, and therefore contributing a negligible amount of gravel to the beach. However, as the district of Wakanui is approached a change gradually develops; the country seems wetter, the coastal gullies are longer, their headward erosion is more pronounced, and their floors are occasionally occupied by permanent streams, and these carry a considerable amount of gravel to the beach. In general, they reach it at grade, but at times erosion by the sea is more effective than any lowering of their beds by stream action, and their seaward end terminates in a discordance. A good example of this is the gully where the Ashburton seaside resort is situated.

The most important of the streams north of the Ashburton is the Wakanui Creek. The lower reaches of its valley take the form of a flat trench, up to half a mile in width, gradually increasing in depth from a few feet near the town of Ashburton to about sixty feet near the coast. Here two clearly defined terraces flank the marginal rise. The stream meanders on the floor of this trench in well-developed loops. When one looks at the seaward reaches of this trench, it is difficult to imagine that it has been eroded by a stream of the same size as that which wanders on the floor at present, and this, in addition to the well-developed gullying both north and south of its outlet, suggests that in the immediate past some additional amount of water was available. A former wetter climate is suggested, but, if so, the dryness of the country further north cannot be explained, therefore some other cause must have been responsible. It is probable that the Wakanui Creek itself received a substantial contribution of water either by overflow or by general seepage from the North Ashburton River. The head of the creek lies in close proximity to a bend of the river about three miles north-west of the town of Ashburton, and indeed there is no impossibility that the lower reaches of the creek may not have been occupied by a distributary of the river coming in from this locality or perhaps from lower down near Elgin. But this would not explain the formation of the coastal gullies immediately north and south of the creek. The whole circumstances of the coastal belt both here and south of the Ashburton River in the neighbourhood of Longbeach point to the existence of impervious beds below the surface gravels of the plains which have intercepted the drainage of the country towards the sea in this section of the coastline, whereas they are absent further north towards the Rakaia.

A feature of the lower courses of both the Wakanui and Ashburton should be noted. First of all, the width of the beds of both streams near the coast is approximately the same, viz., about half a mile, and they both enter the sea at grade. The sea-cliffs flanking the river beds are approximately the same (Figs. 3 and 4), that is about sixty feet in height, and the height of their bordering terraces gets lower as they are followed upstream. This reduction in height proceeds at a rapid pace in the case of the Wakanui, and terraces are almost non-existent near the town of Ashburton. In the main river they also decline rapidly in height when followed upstream till they practically disappear near Elgin, about six miles from the coast. There is here evidently some break in the grade of the stream as related to the grade of the adjoining plain. The height of the Ashburton terrace stairway near the coast is determined by the susceptibility of incompetent beds to both marine and stream erosion, and the river is able to reduce its bed in the lower reaches and enter the sea at grade in spite of the rapid erosion by the sea. But this effect diminishes upstream till it disappears about six miles from the shore. From this point upstream the grade is the same as before and corresponds roughly to that of the plains. In the case of the Rakaia and Rangitata, the terraces are lowest at the mouths of the rivers and increase in height upstream.

### III. *Ashburton River to the Rangitata River*

The moist marginal fringe of the plain continues south of the Ashburton River, and is most fully developed in the vicinity of Longbeach and Lowcliff. In parts it is definitely swampy, and springs and small permanent streams are frequent, the largest being the Hinds River. Haast referred to this (*loc. cit.*, p. 399) as lying between the Ashburton and Rakaia—the last-named river should be the Rangitata—and that it was drained artificially through shingle beds in front. However, the Hinds drains to a part of the coast where the cliffs are lower than at any other spot with the exception of those in the immediate vicinity of the Rakaia and those near Lowcliff.

The reason for the swampy nature of the land is not quite clear to me. It may arise from the fact that the area lies between the seaward extension of the fans of the Ashburton and Rangitata, but this does not explain its existence entirely. A sub-surface layer of impervious material probably underlies it, and intercepts in its passage to the sea the leakage from three rivers in close proximity, viz., the Hinds, Ashburton and Rangitata, as well as ground water from the part of the plains lying to the north-west. In wet seasons, that is, when the annual rainfall lies between thirty-two and thirty-five inches, the springs become active in the area behind the coast, and the amount of surface water presents a serious problem. It remains to be seen to what extent the Rangitata Irrigation Scheme and the consequent increase of surface water which it brings to the plains will affect the drainage of this area.

The sea-front of this stretch is also determined by a cliff. At the northern end it is just over sixty feet in height (Plate 2, Fig. 5), while at Longbeach, six miles to the south-west, it is forty-five feet, at the north side of the mouth of the Hinds about thirty feet. When followed further it falls in height so that for long distances near Lowcliff it does not exceed fifteen feet, and in places does not reach ten feet, and is hardly worthy of the name of "cliff." Further south again it rises, and at the mouth of the Rangitata it is thirty-five feet. So that the statement on the contoured map recently issued by the Survey Department that the coastal cliffs on this stretch rise to from forty to sixty feet needs some revision.

In this stretch the coastal cliff is cut by numerous gullies, some of which are occupied by permanent streams, as, for example, that near Longbeach homestead; another such discharges into the lagoon at the mouth of the Hinds River. Many are short and usually dry. Those occupied by permanent streams enter the sea at grade, but the dry ones frequently end in a cliff as is the case further north.

It should be noted that the river terraces at the mouth of the Hinds resemble those of the Ashburton in that they are higher at the mouth of the river and decline in height when followed upstream, the reason being the same as in the case of the Ashburton (secantea).

### 4. ESTIMATE OF RATE OF EROSION

It is very difficult to estimate the rate of recession of the coastline since the beginning of settlement of the area. Some farmers on exposed stretches say that they have lost along their sea-frontage about two feet per year, and the ends of fences terminating in the cliff testify by their overhang of the edge that this estimate may be reasonable. On the other hand, some farmers say that they have experienced little or no loss. The end of the road at the Raikaia Mouth Settlement has been moved about a chain since the place was first inhabited, and an old well lies in the lagoon fronting the present shore. The road along the cliff or bank to the north has been cut back by the waves, and the same has happened on the stretch of coast near Lowcliff, where the road has had to be moved back about a chain.

Considering the large amount of gravel brought down by the rivers it might be expected that the coast near their mouths would show some amount of prograding, but this does not occur or the forward progression is very slight. In every case a barrier beach of shingle is disposed across the mouth of the river, generally abutting against the base of the cliffs on the south side (Fig. 5), but overlapping them to the north (Figs. 2 and 4), and behind this barrier beach of shingle lies a lagoon into which the river discharges, but with the barrier breached at some point to allow the surplus water to escape to sea. Those near the Rakaia and Hinds have already been referred to, the northward extension of the former being at present very noteworthy. The overlap of the barrier on the north side of the major rivers is no doubt due to the movement north of coastal material during heavy southerly seas. It might be thought that this barrier would protect the base of the cliffs, and so it does normally, but when the river mouth has moved so that it lies oppposite the cliffs, there is no protection by the barrier and the sea enters the lagoon to break against their base and to erode them rapidly. This goes on till the position of the river-mouth changes and a new breach in the barrier beach is made so the part of the cliff formerly eroded has again the protection afforded by the barrier. While the river makes its excursion in the northerly direction a considerable amount of erosion of the northern bank occurs owing to attacks by the river itself as distinct from the action of the sea, as a result of which the northern bank of the river is set further back than the southern bank, seeing that the lagoons are generally developed to the north. But during very heavy storms the waves do break right across the barrier and attack the shore behind the lagoon.

The certainty that the cliffs are being rapidly eroded at present suggests the question of the width of the strip which has been removed from the margin of the plain in the past, but the answer cannot be given with any definiteness. First of all, if the slope of the surface of the plain had continued seaward at the same angle at that of the last half mile between Chertsey and Wakanui, viz., twenty-six feet to the mile, it would have intersected the surface of the sea about two and a-half miles from the present shore. If the inclination of the plains had been flatter the line of intersection would have been further out to sea, and of course, had the angle been steeper—a most unlikely condition—it would have been nearer the shore. These figures assume that the land was stationary. Whatever has happened to the area between Wakanui and Chertsey, it is certain that depression of the land has taken place at the two ends of the coast as has been mentioned earlier. The even form of the sea-bed—to be referred to later—extending as it does for some thirty miles off the present shore, does suggest a lowering of the land. The late Professor W. M. Davis puts (personal communication) a maximum width of two miles that can be eroded from a coastline without change in level of the land, so that it is possible that the depression which affected both ends of the area also affected the middle portion.

### 5. Features of the Sea-bed

The question now arises as to the destination of the products of erosion of the coast and those poured in by the rivers. Wherever a cliff occurs it is buttressed by gravel transported by the waves. Except for the north side of the mouths of the rivers this lies right against the base of the cliff. All the evidence points to a general movement to the north and this accounts for the great accumulations between Lakes Ellesmere and Forsyth and on the southern shore of Banks Peninsula. Although these accumulations at the northward end of the beach are very great, they must represent only a fraction taken from the shore and deposited offshore. The material at the top of the beach is usually coarse and that at lower level increasingly finer, but it is only rarely that sand appears and then almost entirely at low water. The slope of the beach is usually about five degrees, but steeper at its upper levels.

The only source of information concerning offshort conditions is that furnished by the latest Admiralty chart (1944) of the sea in the vicinity. This shows a gently sloping sea-bed extending for a distance of over thirty miles with no irregularities whatsoever. The record shows that it consists chiefly of sand with sandy mud and shelly sand in minor proportions. The eleven fathom line runs almost parallel with the coast and four miles distant from it, so that the bed has an initial slope of sixteen feet to the mile, compared with twenty-six feet to the mile of the plain between Chertsey and the sea. The thirty fathom line is sixteen miles from the shore and the slope very similar, viz., sixteen feet to the mile. The thirty fathom line is thirty miles from the shore and the slope of the bed in this strip nine and a half feet to the mile, so that there is a slight flattening. However, the next four miles show a steeper slope, and the depth increases by another eleven fathoms, so that this line marks the edge of the continental shelf, if it exists. I have given in another article (1943, p. 17) evidence that depths of about forty fathoms are to be found one hundred miles from Banks Peninsula on a direct line to the Chathams. It should be noted that according to the chart the depth of the sea is very irregular off that peninsula and similar depths are to be found only five miles from the coast The depth of the sea off the plains and the nature of the bed are accurately portrayed in a diagram in Professor Cotton's *Geomorphology* (1943, p. 413) and his explanation of deposits offshore apply entirely in this case.

One interesting fact is mentioned on the chart, viz., that during heavy south-easterly gales an inset takes place towards the shore. This accounts for the nature of the sea-bed and for the relative shallowness of the sea offshore, for these winds have a very important influence on the transport of detritus along and away from the shoreline. In this connection I refer to an account of experiments on the transport of detritus by the sea made by Brigadier R. A. Bagnold, a summary of which is given in an address to the Challenger Society entitled "Experimental Work on the Movement of Coastal Sands and Shingles" (*Proc. Geol. Soc.*, 1947, pp. 66–68). A case he mentions appears to satisfy the conditions off the beach under consideration. He says, "A shoreward wind may stop or reverse the shoreward drift at the bed by circulating water shoreward near the surface and thus causing an outward drift below." I have unfortunately no precise data of the height of the waves during storms, but waves have washed right round houses built at twenty-five feet above sea-level near the mouth of Lake Forsyth, on a continuation northward of the stretch of coastline under consideration (Speight, 1930, p. 160). The waves are thus large and competent to explain the character of the sea-bed and the submarine profile offshore in the light of Bagnold's statement. The southerly waves are by far the most potent influence, but mention should be made of the Canterbury nor'-wester, an offshore wind, very strong in spring and summer in this locality. In this case the waves breaking on shore are feeble, but while the wind blows, a temporary current is formed which must have some effect on the lighter material and help to distribute it offshore.

## REFERENCES

BAGNOLD, R. A., 1947. Experimental Work on the Movement of Coastal Sands and Shingles. *Proc. Geol. Soc.*, pp. 66–8.

COTTON, C. A., 1942. *Geomorphology*. Christchurch.

HAAST, VON J., 1879. *Geology of Canterbury and Westland*. Christchurch.

HILGENDORF, F. W., 1907. The Influence of the Earth's Rotation on the Course of the Rivers on the Canterbury Plains. *Trans. N.Z. Inst.*, vol. 39.

SPEIGHT, R., 1930. The Lake Ellesmere Spit. *Trans. Roy. Soc. N.Z.*, vol. 61.

——— 1941. The Rangitata Glacier. *Trans. Roy. Soc. N.Z.*, vol. 71.

——— 1943. Geology of Banks Peninsula—A Revision. *Trans. Roy. Soc. N.Z.*, vol. 73.