The Raised Beaches of the North East Coast of the South Island of New Zealand.

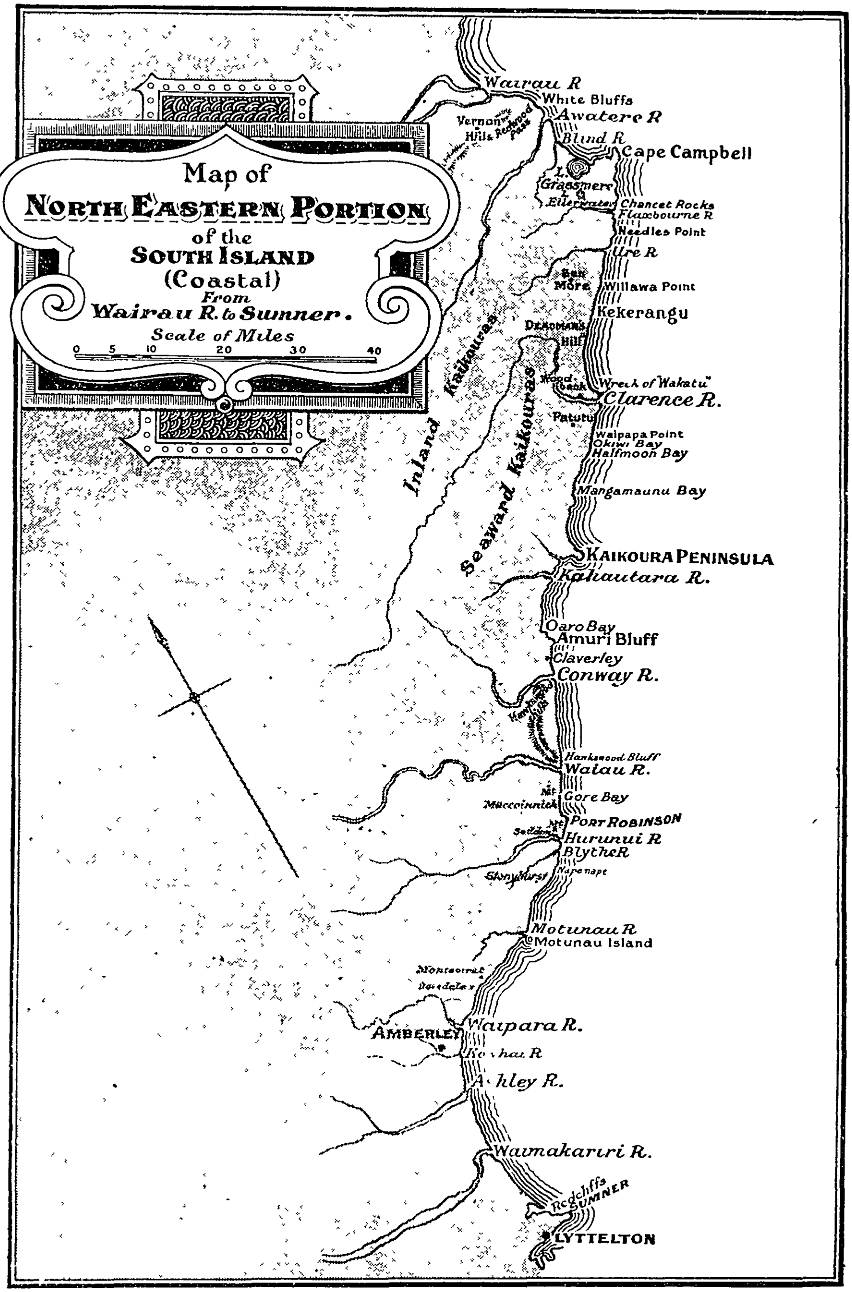
By G. Jobberns, M.A., B.Sc.,
Teachers' Training College, Christchurch, N.Z.

[*Read before the Philosophical Institute of Canterbury, 6th June, 1928, received by Editor, 13th August, 1928; issued separately, 23rd November, 1928.*]

Contents.

Introduction.

This paper embodies the results of an investigation of the evidence indicating changes in the level of the land on that part of the New Zealand coast extending from the Wairau River to Banks Peninsula. Notes on shore-platforms have appeared in the writings of many New Zealand geologists but these have generally been


Map of
NORTH EASTERN PORTION
of the
SOUTH ISLAND
(Coastal)
From
Wairau R. to Sumner.
Scale of Miles
0 5 10 20 30 40
Wairau R
White Bluffs
Awatere R
Vernon Hills
Redwood Pass
Blind R
Cape Campbell
L. Grassmere
Chancet Rocks
Flaxbourne R
Needles Point
Ure R
Ben More
Willawa Point
Kekerangu
Woodbank
Wreck of Wakatu
Clarence R.
Patutu
Waipapa Point
Okiwi Bay
Halfmoon Bay
Inland Kaikouras
Seaward Kaikouras
Mangamaunu Bay
KAIKOURA PENINSULA
Kahautara R.
Oaro Bay
Amuri Bluff
Claverley
Conway R.
Hawkswood Bluff
Waiau R.
Gore Bay
PORT ROBINSON
Hurunui R
Blythe R
Motunau R
Motunau Island
Waipara R.
AMBERLEY
Ashley R.
Waimakariri R.
Redcliffs
SUMNER
LYTTELTON

quite subsidiary to other work being done at the time. As an inevitable result the published observations of many of the earlier writers contain widely divergent estimates of the amount of uplift (or subsidence) indicated by coastal features in the same locality, and any attempt made at correlation of these is unsatisfactory, and comes little nearer to solution of the problems presented or to correct interpretation of the evidence of change of position of the shore-line. While the present writer has made the fullest use of the published observations of geologists who have previously visited this part of the coast, notably that of McKay, Hutton, Haast, Park, Cotton, Thomson, and Speight, each section of the coastline described has been examined in some detail, and as far as was considered necessary for correct interpretation of the features of the present shore the geological structure of the adjacent land has also been investigated. During the course of this work the many gravel deposits encountered in the coastal areas were also examined, but in order to avoid undue length of this paper, discussion of these will be reserved.

Work in such an extended field has involved considerable expense, which has been largely borne by a grant from the New Zealand Institute for which the writer's thanks are gratefully recorded. The writer also takes this opportunity of expressing his thanks to many friends and college students who have accompanied him on field-expeditions and to others who have placed at his disposal facilities for carrying out the field-work. To Messrs. G. Gunn, of Seddon, A. Thomson, of Flaxbourne, Montague Wiffen, of Kekerangu, and E. Stocker, of Conway Hills, his thanks in this latter respect are more especially due. The writer also gladly avails himself of this opportunity of expressing his gratitude to Professor R. Speight for his kindly interest in the work, and his assistance on many occasions during its progress.

Part 1.—General Description of the Coast.

A. The Wairau Plain.

The low swampy plains extending inland from the mouth of the Wairau are in marked contrast to the elevated terraces terminating at the coast-line in bold cliffs (up to 350 ft.) in the valley of the lower Awatere. The parallel lower portions of these valleys are separated from each other by the immensely thick gravel-beds of the Vernon Hills, while to the immediate north of the Wairau Plain lies the "downthrown area" of the Marlborough Sounds. The origin of the Wairau Plain has been discussed by Cotton (1913A, pp. 316-22) who describes the northern boundary as an old shore-line running north-eastward from the Tuamarina Valley to the sea—a line of facetted spur-ends which might have been produced by (1) recent faulting, (2) lateral cutting by the Wairau River, or (3) marine erosion. In the south, too, the spurs running out from the main ridge of the Vernon Hills to the Plain are all similarly truncated, ending in fresh-looking steep triangular faces. If this resulted from recent faulting, the fault-junction between the hills and the plain is now completely masked by more recent fan-deposits of lateral streams. The wide sweeping curves of the cliffed spur-ends suggest that either the Wairau River once flowed round the base of the Vernon Hills to enter the sea near the Big Lagoon or that, which seems more likely, a wide arm of the sea occupied the lower valley. Conditions then were no doubt similar to those obtaining simultaneously at Lake Grassmere a few miles to the south. Wild (1915, p. 414) points out that the Wairau River has apparently carried no gravel nearer to the sea than the present railway-bridge several miles from the shore-line, and that the material of the boulder-bank came as along-shore drift from the south. In all probability the formation of gravel-spits enclosing lagoons both at Lake Grassmere and Cloudy Bay attended the very recent initiation of a cycle of progradation on this part of the Marlborough coast.

Though Henderson (1924, p. 585) suggests that the site of Blenheim has been slightly uplifted, and McKay states that an elevation of 25-30 ft. caused the separation of the neighbouring Queen Charlotte and Pelorus Sounds, there is positive evidence that the most recent movement of the Wairau Delta area has been one of depression (Lyell, 1868, p. 87; Suess, 1906, vol. 2, p. 28; Buick, 1900, p. 332). The writer has not examined the northern edge of the Wairau Plain nor the adjacent Sounds area, but accepts the explanation offered by Wild (*loc. cit.*) and noted by Cotton (1913A, p. 321), that the plain was formed by infilling of an enclosed lagoon with deltaic deposits advancing seawards, and the further raising of the surface by successive floods. In this manner the land could quite well have been built out seawards in spite of an intermittent subsidence of the whole area. However, the question as to whether the Sounds area has actually been submerged far below its present level, and since been partially resurrected by the general uplift so profoundly affecting the remainder of the coast does not seem to have been explored, and this is beyond the scope of the present paper. Cotton (1913A, p. 318) has estimated the extent of submergence of the Sounds area at from 250 ft. to 500 ft., but this does not necessarily afford any indication of the amount of sinking of the Wairau Plain, which appears to have been determined by trough-faulting with infilling of the resulting depression in the manner described above.

The nature of the junction between the plain and the Sounds area to the north and the Vernon Hills to the south remains obscure. Morgan (1916, p. 19) remarks on the remnants of a relatively modern beach only a few feet above high-water mark, especially well developed between Lake Grassmere and Cape Campbell. In January, 1926, the present writer noted these remnants at many points around the White Bluffs. As they were observed in January, 1927, to have been to a large extent removed by heavy seas during the intervening twelve months, they may not afford thoroughly reliable evidence of recent slight elevation of the land. If, as Morgan believed, they indicate a very recent uplift, their immediate proximity to the sunken area of the Wairau Plain suggests that the limit of the sinking block is very sharply defined indeed by the northern base of the Vernon Range.

B. THE VERNON RANGE TO LAKE GRASSMERE.

1. *The Vernon Range*: From the northern base of this range to the point where the Limestone Range reaches the sea about a mile to the east of Lake Grassmere, the coastal area to be described in this section consists entirely of younger Tertiary rocks. These are the stratified gravels of the Vernon Hills and the friable sandy mudstones or marls (the Awatere beds of McKay) which extend for some miles up the Awatere Valley, occupy nearly all the basin of the Blind River, completely encircle Lake Grassmere, and extend across the middle valley of the Flaxbourne River almost to the basin of the Ure.

From Taylor Pass to the sea the Vernon Hills are composed wholly of gravels which can also be traced for many miles farther up the southern side of the Wairau Valley. The hills form a more or less flat-topped dissected ridge rising gently inland from a height of nearly 900 ft. at the White Bluffs where they are truncated by the sea in magnificent cliffs. Some 2½ miles in width, they rise abruptly in sub-maturely graded cliffs from the lower valleys of the Wairau and Awatere rivers between which they form an effective barrier. Although dissection has produced a system of lower rounded spurs running out from the main ridge, the summit of the hills presents a remarkably even sky-line (Cotton, 1914A, Fig. 3, p. 288), and it seems very probable that parallel faulting determining the direction of the major valleys on either side has been to some extent responsible for their isolation in their present position.

The extent of the component gravels is so prodigious as to have caused some speculation as to their mode of origin. Park (1911, p. 522) describes them briefly as "a great pile of fluviatile drifts over 1,200 ft. thick," with a basal layer of glacial debris. He states further, "In places they rest on the older Pliocene clays of the Awatere series," and again, "That they are Pleistocene seems almost certain." McKay, too (1886, p. 123; 1890A, p. 168), considers them to be of a younger age than his "Great Post Miocene Conglomerate." The writer examined sections in the Redwood Pass, in railway-cuttings in the Dashwood Pass, in some of the valleys between the Redwood Pass road and the sea, as well as in the high cliffs at White Bluffs. This latter coast-section shows the gravels to vary considerably in nature from brown loosely-cemented conglomerates where the shore-line has retreated somewhat from the base of the cliffs in the north, to fresh-looking grey sandy shingle in the rapidly-receding cliffs a little farther south. About half way round the bluff, the grey sandy, well-stratified type passes up into highly ferruginous brown beds, the change from one type to the other being in places very gradual. Here the cliffs are marked by lines of fault generally of small displacement. No beds other than these stratified gravels with a uniformly low south-easterly dip are seen in the cliffs until the northern border of the Awatere Valley is reached. Here the cliffs are lower and graded somewhat and the section is obscured, but there is a very abrupt change to the characteristic sandy marls (Awatere beds) in a zone of considerable disturbance due to faulting.

Examination of remarkable sections exposed in narrow defiles debouching at the shore near the Wairau Plain, shows considerable variety in texture of the gravels from well-stratified sandy beds to coarse banded conglomerates with large rounded and sub-angular boulders and interstratified lenses of sandy mudstone. These defiles, with vertical or overhanging walls are often of great depth and are extremely narrow, indicating their rapid erosion consequent on recent uplift. The sub-angular nature of the gravels and the medium to fine texture of the greater part of them, though boulders up to 2 ft. in diameter are by no means uncommon, suggest that they are fluviatile or fluvio-marine deposits transported with considerable velocity. There is, however, no evidence except, perhaps, the immense size of the deposits to indicate the fluvio-glacial origin suggested by Park (*loc. cit.*, p. 522).

That the Vernon Range has recently been uplifted some 1,000 ft. to 1,200 ft. cannot be doubted, but marine erosion has caused such rapid recession of the cliffs as to remove almost completely any traces of pauses in the process of emergence. The only remnants of terraces which may reasonably be assumed to be of marine origin are found in the extreme north-eastern area. These stand at 300 to 350 ft. and at 525 ft. However, a better record of stages in the recent elevation is preserved in the immediately adjacent valley of the Awatere River.

2. *The Lower Awatere Valley*: For the purpose of the present paper this area has been adequately discussed by Cotton (1914, pp. 288-89). River-terraces are remarkably well developed, nearly horizontal caps of alluvial gravel being deposited unconformably on the planed edges of the Awatere marls which comprise the basement-rock of the whole coastal area. Everywhere the terraces end abruptly at the shore-line in bold cliffs, which, in the neighbourhood of the Blind River, attain a height of 350 ft., although the surface-cover of recent gravels is discontinuous here. The amount of elevation observed by Cotton agrees very well with the evidence obtained from other parts of this coast, and uplift with pauses at 120 ft., 350 ft., 550 ft. (?), and 800 ft., inferred by him from the present position of river-terrace remnants may be correlated closely with remnants of shore-platforms in neighbouring localities. Here the coast has suffered severe retrogression leaving a somewhat prominent salient where the Awatere River now enters the sea.

3. *Lake Grassmere*: Cut off from the sea by a spit of fine sandy gravel reaching a height of 15 ft. and made up of two distinct barrier beaches, this is now a circular sheet of water nowhere more than 2 to 3 ft. in depth and sometimes quite dry. Cliffs of mudstone, fresh looking and steep on the southerly side and graded and grass-covered in the north extend right round the margin of the lake-basin. The obviously recent marine origin of these cliffs and the rapid rate at which the lake has been known to have silted up since the advent of agriculture, suggest that the sea has abandoned a wide bay very late in Quaternary time. When the land was 120 ft. lower than now, the sea extended to the middle valley of the Flaxbourne River near Ward, and a little earlier with the general level depressed some 350 ft., it no doubt reached almost to the Ure. A long narrow depression lying behind the sharply faulted block of the coastal Limestone Range and widening considerably at the site of the present

lake, was then occupied by the sea, and the formation of the spit accompanying very recent general progradation of the coast, with subsequent rapid infilling of the remnant, merely represents the final stage in the natural reclamation of a very considerable area. Cotton (1914, p. 293, footnote) has observed evidence of strong tilting or warping of the surface to the south-east of Lake Grassmere, and he suggests that it is probably in sympathy with or forms one boundary of a kind of cauldron-like subsidence forming a bay from which the present lake developed. It is apparent, however, that both Lake Grassmere and Lake Elterwater are remnants of the same arm of the sea, and the tilting or warping noted by Cotton may perhaps be attributed to movement connected with the Limestone Range fault-zone, more or less contemporaneously with the general elevation which rejuvenated the streams concerned.

Lake Grassmere to the Needles Point: The topography of this area is dominated by a narrow, sometimes razor-backed ridge of limestone extending from a point about a mile to the east of Lake Grassmere to the mouth of the Flaxbourne River. Near Lake Grassmere the rocks that form it strike N. 50° E. dipping S.-easterly at an angle increasing from 50° to 75° in an extensive wave-levelled reef. Here the limestone is thinly banded with interleaved layers of greensand, and is much disturbed by the great fault which has determined its landward margin, and which has so completely crushed the stone at Flaxbourne (Morgan, 1916A, p. 19; 1916B, p. 15; 1919, p. 199). It appears on the coast again at the Chancet Rocks where it shows extraordinary disturbance of dip and strike, passes across the lower Flaxbourne Valley to Weld Cone, the Needles Point, and a reef opposite the mouth of Mirza Creek where, steeply tilted seawards, it has regained its normal strike almost parallel to the coast. It is probably the same band of limestone which appears again at intervals at the shore-line, notably at Willawa Point and Deadmans Creek, at both of which places it dips steeply to the north-west. From Lake Grassmere to the Chancet Rocks the general dip of the beds is south-easterly. Then follows a zone of acute distortion and faulting extending from the Chancet Rocks to the neighbourhood of the Ure River, to the south of which the dip changes abruptly to the north-west. This general direction of dip is preserved throughout an area somewhat dislocated by faulting, until the south bank of the lower Clarence Valley is reached where the beds are folded into a syncline sharply bounded inland by a fault.

This section of the paper, however, is concerned only with a description of the area on the seaward side of the Limestone Range referred to above. In McKay's description of the locality (1877, map and sections, p. 188), he refers to the enormous thickness of grey marls (8,000 ft.) developed here. Morgan (1916A, p. 18) doubted the accuracy of this estimate, suggesting that the existence of a fault in the section might necessitate its revision. The writer examined the coast-line section from the limestone reef near Lake Grassmere to the lighthouse at Cape Campbell—i.e., McKay's section (AA map, p. 188) at right angles to the general strike of the beds. It is very difficult to observe the direction of dip of such marls as are exposed in the cliffs. Near the limestone reef they stand almost vertically and show sharp contortion over some distance, but near Fisherman Creek the dip has flattened somewhat, becoming flatter still near Mt. Tako. Just past this point hard bands exposed in the shore-platform at low tide indicate a reversal of dip to the north-west, though stratification is not shown in the cliffs. At the cape the dip is seen to be south-easterly again at about 40°. Whether the reversal of dip is due to the faulting suggested by Morgan or to simple folding is not clear but in any case McKay's estimate of 8,000 ft. probably very much exceeds the actual thickness of the beds. The marls are, however, developed over a wide area and also form extensive reefs off shore for several miles down the coast.

Rock Platforms: In the neighbourhood of Cape Campbell large areas of well-planed surfaces cut in the soft grey marl are exposed at low tide both on the east and west sides of the promontory, while a reef extends off-shore from the cape itself for nearly half a mile. On the east side, where the strike of the beds is parallel to the shoreline, flat wave-cut surfaces can be traced along the coast for several miles, while harder fragments of reefs project above the sea upwards of a mile from the shore. On the west side, i.e., between Cape Campbell and Fisherman Creek, the marl cliffs are receding rapidly. The marl is generally uniformly soft throughout, giving a very even surface to the cut platforms, but some two miles south of the cape occasional hard bands stand out like walls 6 to 8 ft. above the general level. The inner edge of the platform at the cape is loaded with drift-material piled up in two distinct terraces rising about 11 ft. above high-water mark, but this may not necessarily be due to recent uplift when the neighbouring cliffs near Mt. Tako are being attacked so vigorously by the sea. With excessive alongshore drift of waste, the large protruding reef at Cape Campbell would act as a breakwater, causing the loading of the platform. The very great seaward extension of the cut platform exposed at low tide suggests, too, that its inner edge is actually not above high-water mark.

Raised Shore Platforms: A general view of this area from any point on the summit of the Limestone Range suggests some former uniformity of surface-level in a land now sub-maturely dissected by streams, notably Fisherman Creek following a north-easterly course along the base of the Range, and others such as the Boo Boo Stream and Canterbury Gully following a course to the south-east. The only notably high land is Mt. Tako (642 ft.), a flat topped mass in the extreme north-east. Similar flat surfaces up to 471 ft. occur just north of the Boo Boo Stream, but by far the greater part of the area is not higher than 350 ft. The only definite remnants of recent marine deposits found by the writer occur at Long Point, where the steeply-tilted marl beds are capped unconformably by thick beds of marine pebbly gravels and sands up to a height of 160 ft. These are probably the deposits referred to by Morgan (1916A, p. 19), though McKay (1886, p. 125) says, "They (high-level gravels) are absent along the whole coast line from Cape Campbell to Kekerangu."

Both Morgan (1916A, p. 19) and Cotton (1914A, p. 286) refer to a remnant of a shore-platform at Cape Campbell, the former stating, " The projection forming Cape Campbell is flat-topped, and is clearly a fragment of a sea-worn terrace formed when the land was roughly 200 ft. below its present level.'' While the general level of the much dissected land immediately behind the projection of the cape itself is fairly uniform at 330 ft. to 350 ft. the projecting portion is simply a razor-backed ridge, a remnant which has survived the attack of the sea on both sides only by the recent accumulation of protective drift-material at its base. It is by no means certain or likely that it represents a fragment of a wave-cut platform at 200 ft. Much more convincing evidence of an elevation of 150 ft. or so is afforded by the rejuvenation of stream-valleys and deposits of gravel on the summit of marine cliffs in the immediate neighbourhood of Lake Grassmere. Here, too, are flat-topped spurs rising to 250 ft. near the point where the Limestone Range is truncated by the sea. These may possibly indicate a period of standstill at that level.

The writer took advantage of an opportunity to examine the country in the neighbourhood of Mr. A. Thomson's ''Chancet'' homestead. Here the Limestone Range attains its maximum height of some 1,100 ft., while on its steep seaward face is a very pronounced and continuous ledge at 800 ft. Whether this may be regarded as a remnant of a cut platform is by no means certain, but its height can be correlated with undoubted evidence from the Awatere Valley recorded by Cotton.

Residuals of Rock Platforms at Flaxbourne: Cotton infers uplift of some 6 ft. from flat-topped remnants of a dissected shore-platform in this locality (1914A, p. 293). These seem to be restricted to a small part of the shore-line between the Needles Point and the Chancet Rocks, at both of which points slight elevation may also be inferred from the isolation of rock-stacks. Immediately to the north of the Chancet reef the strand-plain is built of blocks of broken limestone and crushed debris from the steeply-tilted faulted ridge, while the limestone in the reef stands in an almost vertical attitude and strikes N.N.W.-S.S.E. running out to sea in a line of stacks showing most remarkable contortion of the component rock. Then just below the mouth of the Flaxbourne River the limestone strikes N. 26° E., almost parallel to the coast, and dips easterly at 70°. Between Weld Cone and the Needles Point all the rocks are involved in a zone of faulting, and show excessive contortion. and shattering with complete reversal of dip and strike within a radius of a few yards. This remarkable disturbance occurs within a limited area to which the residuals noted by Cotton are restricted. Therefore while elevation of 6 ft. to 8 ft. or perhaps a little more has without doubt occurred here quite recently, the present writer would hesitate to say that it is necessarily a general feature of adjacent parts of the coast, notwithstanding the fact that a narrow rapidly-prograding strand-plain seems almost continuous for a considerable distance.

D. THE NEEDLES POINT TO WAIPAPA POINT.

From the Needles Point to the Ure River the recent strand-plain shows a rapid increase in width, but there is no good record preserved of pauses in the process of emergence. Here are extensive dunes of wind-blown sand, passing southward into large fans of loose shingle deposited by the Ure and the streams to the south of it. The fan of the Woodside Creek rises from sea level to 50 ft. at the Main North Road, in a distance somewhat less than a mile, and the stream-bed is filled with boulders of large size. These alluvial fans play an important part in the prograding process from this point to the Clarence—i.e., in that part of the Marlborough coast where the recent strand-plain reaches its maximum development. Single Hill (503 ft.) indicates the average height of the coastal country, while just below the Woodside Creek bridge there is a very flat ledge at approximately the same height cut in limestone, but capped only with loose sharply-angular chips of limestone showing no sign of marine origin.

River-terraces in the lower Kekerangu area have been described by Cotton (1914A, p. 290; 1918, p. 146), his estimate of a recent elevation of 120 ft. being a conservative one. A general examination of the country indicates that this represents a more recent stage in an elevation amounting to at least 500 ft., which corresponds very closely to that so clearly indicated by terraces in the lower Clarence Valley a little to the south.

The component rocks in the lower Kekerangu area are marls traversed by faults along the line of which at least two of the three parallel bands of "The Great Marlborough Conglomerate" are involved. The greatest of these faults is that which is clearly seen in the limestone in the lower Benmore Stream near its junction with the Kekerangu, and which crosses Heaver Creek where the middle line of conglomerate is involved (McKay, 1890A, p. 173). Evidence of quite recent displacement may be seen at the surface here. Where least disturbed the rocks in this area stand almost vertically or dip north-westerly at fairly high angles. Grey sandy marls are the predominant rocks, and these have offered little resistance to erosion; the surface is therefore of a broadly undulating, sub-maturely dissected type. Near the Napoleon Station Homestead, however, there are two, perhaps three, intrusive sills of basalt, defining the tops of the ridges behind the house. McKay (1886, p. 87) refers to these as interbedded sheets, but the induration of the under-surface of the overlying beds suggests their intrusive nature. These ridges of harder rock are nowhere much in excess of 500 ft. in height, and this may reasonably be supposed to represent the height of a formerly regular surface. There is a noticeable regular increase in height to the north-east near Shaw Fall or the "White Slip," where, owing to the steep angle of inclination of the beds and their broken nature, they slip seawards in great masses to be cliffed by the sea at a point where the usual narrow strand-plain disappears from the coast. Reference has been made by various writers to this part of the coast, more especially in connection with discussion of the Great Marlborough Conglomerate, but this is beyond the scope of the present paper. It is these gravel-beds which form the steep homoclinal ridge of Deadman Hill and the reefs near the mouth of the Kekerangu River. They appear to overlie the marly beds which extend through the coastal cliffs from here to the neighbourhood of the north bank of the lower Clarence Valley.

The only deposits of importance to the present discussion are the thick beds of recent gravels and sands lying unconformably on the planed edges of the marls in the vicinity of the Ngaio Downs Station. It is in the southern portion of this locality particularly that the recent gravel-cap is remarkable for its great thickness, and for a slight landward tilt suggestive of warping. Near Pigeon Hill the following sequence is seen in the upper beds (in ascending order):—

a. Basal gravels, loose well-rounded pebbles of moderate size.
b. Fine sands, well stratified with abundant interstratified bands of pebbles.
c. Coarse rounded boulders in a matrix of fine sand. These beds together have a thickness of nearly 100 ft., and are capped by,
d. Fine sandy clay. 20-30 ft.

These beds are separated from the high-level terrace gravels of the lower Clarence Valley by a high undulating ridge in which Pigeon Hill (966 ft.) is prominent, and from their position they are most probably of marine origin. There appear to be two sets of terraces, one at 300-350 ft., the other at 500-550 ft., but they are of a very fragmentary nature. Between Pigeon Hill and Otu-Kaku Point the marls of the cliffs give place to the thick gravel-beds of the so-called Clarence Delta, to appear again in the end of the razor-backed ridge opposite the wrecks of the "Taiaroa" and the "Wakatu."

The high level terraces of the lower Clarence: The structure of the so-called Clarence Delta was examined in some detail, but correct interpretation of the facts observed is hampered by the writer's lack of knowledge of the geology of the country between Corner Hill and the Kekerangu Valley across the upper Ericaburn.

a. *North Bank*: A section through the northern part of the "Delta" from Otu-Kaku Point to Corner Hill, a distance of three miles, shows the following in ascending order:—

1. Marls, grey, stiff, very argillaceous. Exposed on the extreme seaward end of the "Delta" for a few chains. Strike N. 27° E. Dip north-westerly, 33°.

2. Gravels. The lowest beds exposed are fairly fine gravels with interstratified bands of soft friable sandstone. The contact between the gravels and the underlying marls cannot be seen, but as far as can be judged from dip and strike they overlie the marls conformably. The dip of the gravel-beds which are nowhere seen to be very coarse in texture, but which may be cemented to form a hard conglomerate, continues north-westerly for over 2½ miles. No satisfactory exposures are to be obtained near the Woodbank Homestead, but the writer found no indication whatever of reversal of dip throughout the section.

3. Dark reddish sandstone reduced to a fine sand at a zone of crushing at Corner Hill. A small wedge-shaped mass of this sandstone is involved in a powerful reversed fault, which has also caused considerable crushing of the immediately-adjacent gravel-beds.

4. Reversed fault, running N. and S. (mag.). The plane inclines to the west at 50°.

5. Amuri limestone, forms a steep bluff against the base of which the main stream of the Clarence River impinges. The lime-

stone stands in an almost vertical position, but is much contorted, and the surface involved in the fault is perfectly slickensided.

This section was not seen by McKay, but he notes that Hector examined a section on the east bank of the Clarence in December, 1873, and described the conglomerates as being folded in anticlines and synclines on the north-west side of the Amuri limestone (McKay, 1890A, p. 173). As remarked above, exposures are not good in the high terrace bank in the vicinity of Woodbank, but wherever seen the beds dip persistently to the north-west. The present writer did not investigate the structure in the area to the north-west of Corner Hill examined by Hector, and it is not proposed to discuss in this paper the stratigraphical position of the gravel-beds, but it may be remarked that the chief difficulties in the interpretation of the section lie in determination of the age of the grey marls exposed at Otu-Kaku Point, and in explanation of the occurrence of the brecciated older rocks at the Corner Hill fault-junction.

Unfortunately the only description of this part of the coast is to be found in Cotton's purely physiographical writings (1914A, pp. 286-294; 1916A, pp. 20-47; 1922, pp. 204-208). He attributes the mode of deposition of the gravels to foresetting as shown in typical delta-structure, but on the north bank the gravel beds dip persistently landwards. The only point where the nature or structure of the component gravels has been described at all is in the south bank of the river near the Clarence Bridge—i.e., "The foreset portion of the delta, which, however does not show stratification." (1914A, p. 292). At this point, however, the apparently unstratified gravels form the core of the syncline into which all the beds on the south bank are folded. The upturned edges of the beds in this syncline were then planed off and the thick beds of a recent surface-cap deposited on them. If the gravels were ever deposited as a delta, it was at a very much earlier date than that suggested by Cotton's description, and they do not now exhibit in the slightest degree the structure typical of the foreset beds of a delta.

b. *The South Bank*: The contact between the conglomerate beds and the limestone forming the steep ridges behind them could not be seen at any point near the road past the Waipapa Homestead, nor is it exposed in the valley of the Porangahau Stream a little to the south. There can be little doubt, however, that the great reversed fault described above crosses the Clarence River to reach the sea at Waipapa Point where the excessive disturbance of the strata has been described by McKay (1886, p. 84). Where first seen on the Waipapa road near the limestone, the gravels are exposed in steep cliffs by the roadside. Here they are not very distinctly stratified, but appear to stand almost vertically. Traced downstream towards the bridge, they are seen to dip easterly at a steep angle, flattening noticeably as the Waipapa Homestead is passed.

In a bare sandy ridge where the Main North Road crosses Garret Stream (the first south of the Clarence), the older gravels are seen to dip inland (north-westerly) at 40°, the strike being N. 26° E. Here the younger surface beds lying across the upturned edges of the conglomerates, consist of remarkably uniform material, being on the whole fine-grained with coarser and finer bands alternating with great regularity. The whole series is well oxidized to a deep brown and capped with about 20 ft. of loess-like clay. The sandstone involved in the Corner Hill fault and exposed on the hillside just above it could not be found in position on the southern side of the river, but an elevated flat surface at 350 ft. above Edgecombe, is covered with huge angular blocks of a similar rock indicating its close proxmity to this point.

As far as can be seen, therefore, the southern portion of the "delta" consists of gravel-beds, generally well cemented to form a hard conglomerate, and is separated from the inland limestone ridge by a fault. The existence of sandstone near the fault can be reasonably inferred, but there is no indication of marl-beds corresponding to those exposed at Otu-Kaku Point, these having been removed by marine erosion, and the platform cut in them being no doubt buried beneath the accumulated shingle and blown sand which forms a low dune-covered strand-plain upwards of a mile in width. To the south of the river all the beds are involved in the syncline, and Hector's record (*loc. cit.*) of similar folding of the gravels to the north-west of Corner Hill, indicates that the extent of the gravel deposits is enormously greater than that indicated in Cotton's map (1914A, p. 290; 1916A, p. 36; 1922, p. 206).

c. *Evidence of Uplift*: McKay seemed to be somewhat uncertain as to the distribution of the gravels of the lower Clarence Valley, but he stated definitely his opinion that the first low terrace north-east of the valley is a raised beach (1886, p. 126; 1890A, p. 182). Cotton inferred elevation amounting to 500 ft. (1914A, p. 291; 1916A, p. 39). From the evidence of valleys dissecting his ancient uplifted delta, he also inferred a pause in the uplift process at about 300 ft. (1914, p. 292). Reasons will be advanced later for regarding Cotton's claim (1916) that the East Marlborough Coast is a "mature resurrected fault coast with a projecting delta built by a large river —the Clarence" as a pure hypothesis, but his estimate of the amount of recent elevation is a quite conservative one.

The lower projection on the north bank of the Clarence terminating in Otu-Kaku Point—i.e., the eastern extremity of Cotton's raised delta—is simply a razor-backed ridge from which the surface-cover of horizontal beds has been removed, and which has survived complete destruction by the combined attack of the sea on one hand and the river on the other, only by the very recent initiation of a cycle of progradation following one of rapid cliff-recession. In this respect it is almost precisely similar to the promontory at Cape Campbell.

At Corner Hill the summit of which stands at 777 ft., capped with terrace gravel and angular blocks of limestone (though the limestone outcrop is now denuded much below this), the height of the present river channel is about 130 ft. So there is evidence here of elevation amounting to some 650 ft. The gravel-beds are seen to have an enormous development, lying under and around Corner Hill, preserved so long only by the now very thin buttress of limestone against which the main river impinges, and extending out to the coastal cliffs through Pigeon Hill (966 ft.). The river once flowed just to the north of Corner Hill, where it has left a terrace deeply dissected now by the Rika, May, and Donkey Streams. From this point it can be seen that Pigeon Hill itself has been terraced at an accordant level, which can be traced to the surface of the flat-topped promontory shown in Cotton's sketches (1914, p. 291, etc.). This promontory is a remnant of a high-level river-terrace which must formerly have extended far to the seaward, and Cotton is mistaken in supposing that its surface slopes away from the river (1914, p. 291).

The combined evidence of river-terraces and remnants of raised beaches in the lower Clarence-Kekerangu area indicates a recent elevation amounting to at least 650 ft., with pauses at 500-550 ft., 350 ft., and 120-150 ft. The writer has no doubt that a similar examination of the area immediately to the north of the lower Clarence Valley would reveal evidence of stages at 800-850 ft. and probably somewhat yet higher.

E. WAIPAPA POINT TO MAUNGAMAUMU BAY.

It is immediately below Waipapa Point, near the mouth of the Mororimu Stream that the limestone of the lower Clarence area makes its last appearance on this part of the coast. From the adjacent Okiwi Bay to the point where the gravels of the recent Hapuku fan reach the shore, the coastal rocks are entirely sandstones. McKay referred these older rocks to his Bastion Formation —i.e., he considered them to be equivalent in age to the Jurassic sandstones of the Amuri Bluff section—and his coloured map (1890, p. 96) shows a strip of the Notocene beds extending from the lower Clarence Valley through the fault-valley of the Puhipuhi to the Hapuku. The mass of older rocks thus isolated on the coast rises to 3,820 ft. in Patutu Peak, and there is every reason to believe that the remarkably regular alternation of rocks of the older and younger series is a characteristic structural feature of the coast, at least from this point southwards. In this locality, however, the relationship of the rocks of the "undermass" to the overlying Notocene beds, and the normal sequence of these beds themselves, has been highly disturbed by faulting. It seems fairly certain that erosion has not proceeded much farther than the complete removal of the Notocene cover from the summit and seaward face of the older projecting mass, which can be imagined to have been completely surrounded formerly by the younger series. Sandstones are exposed on the coastline for some 10 miles, and ragged reefs cut in them project offshore for a few chains at many points. The Notocene beds appear again in Kaikoura Peninsula and in the Amuri Bluff, in both of which places they have been planed by the sea at accordant levels. The narrow, recently built strand-plain, characteristic of the coast to the north of the Clarence, is not developed here, and road cuttings in the steep hillsides are numerous.

It cannot be supposed that this area has escaped the effects of the general movement of recent emergence, but no satisfactory record of former beach-levels is preserved in the harder rock. Evidence pointing to a very recent slight elevation of small amount may be summarized as follows. In Okiwi Bay boulder-beaches resembling three parallel tiers of railway-embankment suggest uplift of 15 to 20 ft. On the south side of the bay a platform cut in the sandstone and having practically no surface cover, slopes down to high-water mark for about two chains. Uplift here might be as much as 20 ft. Slightly raised cut platforms occur almost continuously from this point to the Ohau Stream where there is a flat-topped remnant of a platform at 130 ft. Its surface-cover consists only of angular blocks and fragments of sandstone, but any water-worn material there may have been would not be preserved on this ledge.

In Halfmoon Bay there are low projecting spurs behind which the roadway has been cut. It may be suggested that these formed projections on the surface of a platform similar to the present wave-cut shelf on which are irregular low stacks. Here too are wave-worn caves, one continuous as a tunnel through the bluff at the south of the bay, the other containing a very large well-preserved log of drift-wood cast up by the sea in fairly recent time to a point beyond its present reach. Making all due allowance for the extent to which the floor of the caves may have been raised in various ways since the retreat of the sea, they certainly indicate an elevation of 10 ft. In making any inference regarding elevation of the land in a locality such as this, the observer must make all possible allowance for the power of the sea to cast up material into small exposed bays. Therefore, while the evidence afforded by raised boulder-banks may be misleading, that obtained from raised rock-platforms and water-worn caves may with more certainty be accepted as proof that uplift has recently taken place here to the extent of at least 10 ft. to 12 ft.

F. MAUNGAMAUMU BAY TO THE KAHAUTARA RIVER.

This section of the coast comprises the Kaikoura Plain extending from the southern side of Maungamaumu Bay to the mouth of the Kahautara River, and the low flat-topped hills of the Kaikoura Peninsula. The geology of the Peninsula has been fairly fully traversed by various writers and will not be discussed in detail here. The physiography of the area has also been discussed by McKay (1886, p. 126; 1890A, p. 182), Morgan (1916, p. 19), Park (1911, p. 523), and Cotton (1916A, p. 36). Cotton (1916A, p. 37) describes the Peninsula as an island "now tied to the mainland by the confluent deltas of several streams forming the Kaikoura Plain, where locally the shore line has advanced owing to a very abundant supply of waste from the Seaward Kaikoura Range," while McKay (*loc. cit.*) gives a lucid account of the manner in which this supply of waste has been built up into the great fans of the Kowhai and Hapuku Rivers, to form the Plain.

McKay (1890A, p. 98; 1892, pp. 12-14) describes a great fault-zone extending past the eastern base of Mt. Fyfe, through the valley of the Puhipuhi into the valley of the lower Clarence, and thence north-easterly to the mouth of the Flags River. Commenting on this, Morgan states (1916A, p. 20) that there are probably two parallel faults in the Puhipuhi Valley, and that, "There is certainly strong parallel faulting along the coast-line, as shown by the smashing and crushing of the pre-Quatenary rocks wherever they are exposed. Thus the essentially faulted nature of the coast line is clearly demonstrated." He also draws attention to the fact that the rocks of Kaikoura peninsula are highly disturbed by faulting, a feature noted by McKay (1887, map, p. 76).

Cotton, unable otherwise to reconcile the projection of Kaikoura Peninsula with his hypothesis of a fault-coast, especially exempts this area from the full effects of the great fault, which is supposed to account for the peculiarly straight line of the rest of the East Marlborough Coast. He states (1916A, p. 36) "The initial island was probably the unsubmerged portion of an unevenly depressed seaward block."

No indication of the nature of the basement-rock below the delta-fan gravels of the Kaikoura Plain is afforded by examination of the valley of the Kowhai, but it is a reasonable conjecture that near the eastern base of Mt. Fyfe are remnants of the Notocene beds as are exposed in the valleys of the Puhipuhi, Hapuku, Kahautara, and thence continuously into the valley of the Charwell. The low hills to the west of the Kaikoura peninsula consist of greywackes, and the Notocene beds of the eastern portion, though highly disturbed by minor faults, exhibit a fairly simple folded structure. It may be supposed that after the close of the late Tertiary period of heavy faulting the whole of this area was depressed below sea-level, the highest point of the "island" being now only 358 ft. at the Trig. station behind the old wharf. On this hypothesis it is not difficult to account for the isolation of the "island" by the erosion of the less-resistant portion of the Notocene beds, as a wave-levelled plain emerged in stages to its present height. The re-uniting of the "island" to the mainland belongs to very recent geological time, and the whole series of changes since post Tertiary emergence began no doubt post-dates any major faulting that has occurred here, or at any other part of the north-east coast of the South Island which comes within the scope of this paper.

The terraced surface of Kaikoura peninsula has been noted by Cotton (1914A, 1916A), Morgan (1916A), and Henderson (1924, p. 586). Estimates of the heights of these terraces show considerable variation. The highest point of the upper terrace is 358 ft. as noted above, but as it is only a fragment of what it must formerly have been, the actual level of the period of standstill represented may be somewhat higher. The other two terraces offer more reliable evidence, they being cut in the seaward side of the peninsula at 250 ft. and 140-160 ft. respectively. Near the racecourse the latter terrace is a little lower than this, but its surface is not very regular here, and the writer is of opinion that the most nearly accurate estimate of the amount of uplift indicated by it is 150 ft. Morgan (*loc. cit.*, p. 20) notes the presence of a fluvio-marine terrace just north of the Hapuku River at 100 ft. This no doubt represents the cliffed north-eastern edge of the Hapuku fan. The writer noted the height of these cliffs on the road from Maungamaumu as 90 ft., but is not satisfied that they represent any period of standstill at this level. The cliffs on the face of a receding delta-fan of this type will show almost any variation in height, and no definitely-marine deposits were observed in any of the cliff sections.

The cliffing of the outer edge of the Hapuku fan has provided an enormous amount of material for resorting and transport by the sea, and this is entirely responsible for the enormous shingle-bank in the neighbourhood of Lyell Creek just north of the peninsula (Morgan, *loc. cit.*, p. 20). From high-water mark to the inner bank above Lyell Creek it is approximately 14 chains in width—i.e., almost twice the width noted by Morgan. It rises in a series of four terraces to a height of 21 ft. above high-water mark—i.e., at the summit of the inner terrace on which is the Main North Road. Taking the top of the first bank to represent normal high-water mark, the second terrace is 8 ft. above this, rising another 5 ft. to the rear of the third terrace. Two feet above this, on the face of the fourth or main terrace, a line of drift-wood marks the maximum height of storm-seas—i.e., 15 ft. above normal high-water mark. The main terrace, wide and undulating, rises to 21 ft. above high-water mark, and from its inner edge a steep descent is made to the bank of Lyell Creek, the bed of which is here only 2-3 ft. above high-water mark at a point about a mile from its entrance to the sea at the northern end of the township. Exceptionally heavy seas are sometimes experienced here, and much drift-wood has been cast high up on the terraced-face of the shingle-bank. The wave-force in this exposed bay must be very great, and with an inexhaustible supply of shingle from the cliffed fan of the Hapuku, the formation is readily explained. Once the first barrier was formed an object against which to cast the shingle would be provided, but infilling of the outer bay would cause the waves to break farther from the shore, and some of their power to cast up shingle would be lost. A decrease in the height of the seaward portion would therefore ensue. To infer recent uplift from such a bank is likely to be misleading.

The drift of shingle round the peninsula from the south is interrupted by a reef running out to sea for nearly half a mile at the junction of the limestone and the grey marl near the Maori village on the south side. The rock platform is loaded with drift on its southern side, forming a wide strand-plain and intensifying an appearance of recent elevation, while around the east head of the peninsula the platform is practically free from drift-material, and the sea reaches the base of the cliffs at many points.

Caves noted by Morgan (*loc. cit.*, p. 20), are found near East Head, they being eroded in flaky limestone. The entrance to the caves is in every case partly filled in with broken rubble from the roofs, but Morgan inferred from them elevation amounting to 10-12 ft. At the extreme north-easterly point of the peninsula cliff-recession still seems to be very rapid, there being here an almost level platform cut in the grey marl over half a mile in width. Yet between this point and the old wharf there is a strip of strand-plain 3-4 chains wide formed of two storm-beaches enclosing a lagoon-like flat. This, together with a wide storm-beach at the base of the cliff round the next point suggests considerable recent elevation. Near the old wharf, where the narrow road is built on an old beach of limestone pebbles with numerous included fragments of whale-bones, the roadway is being attacked by the sea which would soon reach the cliff base again.

The extensive rock-platforms indicate the enormous extent to which the peninsula has been reduced in area, but evidence that recent elevation has amounted to as much as 10 ft. to 12 ft. is not altogether satisfactory. It is probable that redistribution of waste from the seaward edges of the river-fans, over the highly-irregular surface of the cut platform, has been to a much larger extent responsible for the narrow strand-plain forming the site of the township and the Maori village. Unequivocal evidence of recent uplift amounting to at least 10 ft. to 12 ft. has been recorded from the coast immediately to the north, but the writer is by no means certain that the movement has been regularly continuous to produce the same amount of elevation at Kaikoura.

G. THE KAHAUTARA RIVER TO OARO BAY.

Although definite evidence of raised shore-platforms is absent from some miles of the coast-line from the mouth of the Kakautara River to Oaro Bay, a coast where greywacke and associated rocks are exposed in the steeply truncated spurs (see Cotton, 1916, Fig. 21, p. 45), complete continuity and approximate uniformity of the recent upward movement cannot be doubted. The raised beaches of the Kaikoura peninsula have their exact counterpart at and near Amuri bluff, whence an embayment of a former shore-line with well preserved terrace-remnants extends to the southern end of the Hawkswood Range near the mouth of the Waiau-ua River.

Cotton (1916A, p. 45) draws attention to narrowness or absence of the continental shelf with a great depth of water about two miles from the land. He states further, "This suggests recent subsidence along a fault line close to the present shore; and the land presents the appearance of a fault scarp (Fig. 21), as though a strip had recently subsided along an arcuate line a little within that of the initial scarp of the resurrected fault coast to the north-east that has already been described. A very similar result might, however, have been produced by offshore subsidence as a result of renewed movement on the original fault (if we may assume that the fault coast now recognized to the north-east formerly extended along this portion of the coast also). Such offshore subsidence would in most cases be followed by increased activity of wave action on the shore, producing a cliffed shore line not unlike that of a young fault coast. Further study in the field is necessary before a more definite statement as to the nature of this strip of coast can be made."

The present writer agrees that the later Tertiary faulting accompanying the Kaikoura orogeny had a profound effect on the topography of this area, and to a large extent determined the distribution of the Notocene beds. A study of the present occurrence of these throws some light on the physiography of the locality. Erosion at Oaro Bay has revealed the classic section at Amuri Bluff, which shows a gentle anticline with the Notocene rocks overlying a core of Jurassic sandstone. McKay's coloured map (1890) shows this sandstone to occur in a similar position at Kaikoura peninsula, though it must be admitted that the shaly rock forming the core of the main anticline there does not resemble the typical "cannon-ball" sandstone at Amuri Bluff. The Notocene beds are developed through the valleys of the Oaro and Hundalee streams to the basin of the Conway River, and they occur again in the valley of the Charwell. In all of these localities they are disturbed by faulting, but they form an almost continuous strip around the base of a great protruding mass of greywacke and separate it from the main block of the Seaward Kaikoura Range. If recent faulting determined the outline of the present shore in the manner suggested by Cotton, then some evidence on a big scale might be expected in the neighbourhood of Oaro, the Hundalee Valley, and the Conway River. Such evidence as there is may be summarized thus:—

a. In the valley of the Okarahia Stream, between the Main North Road and the sea, greensands and sands overlie the Jurassic sandstone which forms the core of the Amuri Bluff anticline. Near the mouth of a tributary stream rising near the saddle over which the Main North Road passes into Oaro, is an exposure of Amuri limestone overlain by grey marl. These beds strike E. 10° N., dipping westerly at 30°. Faulting may be inferred from the repetition of the greensand in the section, this being exposed a little farther up the main stream, but the amount of displacement is not great.

b. In the valley of the Oaro Stream, near the school, limestone and overlying grey marl are seen to dip south-easterly in the north-western wing of the syncline which succeeds the Amuri Bluff anticline. Upstream behind the school greensands are exposed intermittently in the banks, the section being somewhat obscured by recent terrace-gravels. Then limestone appears again in an area disturbed and shattered by faulting. The amount of displacement indicated by the repetition of the limestone is not remarkable. Grey marl containing fucoids is exposed for a considerable distance upstream, until the Hundalee conglomerate (so named here on account of its peculiar distribution in this locality) appears near the Okarahia-Oaro saddle. Morgan (1916A, p. 24) states that a fault determines the relationship of the conglomerate to the grey marl, but the section in the Okarahia Stream about to be described offers an alternative explanation.

c. A tributary of the Oaro Stream issues from a narrow precipitous gorge cut in greywacke to enter the main stream near the school. At the entrance to the gorge the greywacke is disturbed and brecciated, it being traversed by a steeply inclined normal fault running N.E.-S.W. No rocks other than greywacke are involved in the fault and the amount of displacement is difficult to determine.

d. Less than half a mile below the bridge across the Okarahia Stream on the Main North Road, greywacke is exposed in the steep banks for a distance of some 300 yards. There is a very clear contact between the greywacke and the conglomerate beds which are so clearly exposed in the road-cutting about 150 ft. vertically above. The junction is a simple unconformable contact, showing no sign whatever of disturbance by faulting, and the conglomerate consists here of small rolled pebbles of greywacke in a sandy matrix, with occasional large blocks of grey marl a short distance upstream.

Immediately below the first road-cutting exposing the conglomerate, i.e., about ¼ mile from the bridge, another contact between the conglomerate and the greywacke is seen. Here the division-line is nearly vertical, but the greywacke shows no sign of brecciation and the conglomerate lies undisturbed against it. Morgan (*loc. cit.*) states that a reversed fault occurs here. The conglomerate is certainly abruptly terminated against a steep wall of greywacke, but there is nothing to indicate that it was involved in any such reversed faulting subsequently to its deposition. The nature and distribution of these conglomerate beds have an important bearing on our study of earth-movements which may have affected the shore-line. While they contain numerous very large blocks of greywacke, Amuri limestone and grey marl such as those seen in the typical Great Marlborough Conglomerate, the bulk of the material consists of fairly fine well-rolled pebbles, and the sandy cementing medium is often full of shells and shell-fragments. In places the material passes into a sandy marl containing scattered pebbles, bands of gravel or large angular blocks. From examination of the Okarahia section the writer inclines to the opinion that its deposition post-dated any extensive faulting which may have determined the depression in which it appears to lie. There seems, however, no necessity at all to demand any large-scale faulting in explanation of its distribution, for it may merely have been deposited at the base of a cliff of normal marine erosion at a time when, with the land 1,000 ft. lower than now, the sea reached from the present Oaro Valley into the lower basin of the Conway behind Mt. Guardian and the Hawkswood Range.

This is a very useful and simple conception of its mode of origin, for the great angular blocks may now be supposed to have fallen from the cliff against which the beds were laid. There can be no doubt that the deposit is of marine origin, and that it is unconformable to the grey marls. Its Pliocene age is determined, too, by the evidence of fossils collected from the upper parts of it. Thomson (1912, p. 8) gives a list of fossils collected near Oaro, and determined by Suter to be of probable Pliocene age. Thomson, however, supposed these shells to have been contained in a raised-beach deposit, but Professor R. Speight has made collections from the upper conglomerate beds in precisely the same locality, and Suter identified these also as of Pliocene age.

There is therefore no satisfactory evidence that the great block-displacement which Cotton supposes to have determined the coast south of Kaikoura, is continued into the country near Oaro and the Pliocene Hundalee conglomerate does not seems to have been faulted into its present position. It is quite possible and likely that the conglomerate post-dates the Kaikoura orogeny and its present elevation above the sea can be accounted for by a post-Kaikoura elevation of about 1,000 ft., i.e., equivalent to the height of the upper marine terraces. The cliff against which the beds were laid may have been a fault scarp belonging to the Kaikoura orogeny but it is by no means necessary to suppose this.

So there is only the evidence of the fresh-looking steepness of the coastal cliffs and the occurrence of deep water close inshore to support Cotton's conception of a recent fault-coast north of Oaro. Examination of the coast-line concerned shows steep cliffs truncating spurs, the strata highly tilted and disturbed, abundant smoothed slicken-sided faces, and an irregular cut platform of considerable extent. All these features, however, are to be found wherever masses of the older rock are cliffed at the shore-line. On both sides of the mouth of the Oaro Stream are remnants of Notocene beds terraced at 150 ft. and at 360 ft., but no remnants of them are found on the coast between here and Kaikoura, and there are no definite terraces in the older rocks. Since support for the hypothesis of recent large-scale faulting has not been found from examination of the adjacent land, it may be supposed that any such faulting as may have occurred was of the nature of a huge cauldron-like subsidence of the sea-floor some distance from the present shore. However, the cliffing of the coast by marine erosion at a time when the land was higher than now must not be overlooked as a possible explanation of the sudden deepening of the water offshore.

The writer has examined Cotton's description of the coast (1916A) in the field, but has sometimes found it difficult to follow. As far as the disappearance of the Notocene rocks from the coast is concerned, it will probably be found that such disappearance is a regular structural feature, and not necessarily to be attributed to faulting. The alternation of older and younger rocks is most remarkably regular from this point southwards, and recent faulting does not seem to have been a factor in determining the outline of the present coast.

H. Oaro Bay to the Hawkswood Bluff.

With the exception of the well known section at Amuri Bluff, this locality has received comparatively little attention from geologists. Haast (1871) gives a general account of the structure of the district, indicating the succession of rocks down the coast from Amuri Bluff to the Conway River, and describing a section exposed in the north bank of that river. Buchanan (1868, pp. 38 and 40) makes brief reference to the structure at the mouth of the river, while McKay (1886, p. 126; 1890A, p. 182) states that he did not examine the terraces to the south of it. His coloured map (1890A), however, shows roughly the position of the gravel-beds there—gravels which he, for no expressed reason, assigns to the same formation as his "Great Post Miocene Conglomerate." Hutton's map accompanying his paper on the North East Coast (1877, p. 56) shows the rocks of his "Maitai Formation" exposed on the coast-line continuously between the Conway River and Gore Bay.

For the reason that much of this area has hitherto been unexplored by the geologist, and that it contains raised shore-platforms rivalled in extent only by the Motunau Plain, it will be described in some detail in this paper. In view of the fact that a University student has lately commenced a study of the geology of the lower Conway basin, the stratigraphical relationship of the coastal gravel-beds to those in the neighbouring Hundalee Valley, and to the associated richly fossiliferous sandy marls, will not be discussed.

McKay's coloured map (1890A) shows a threefold division of the older rocks in this locality—i.e., his Bastion Formation is represented in the core of the anticline in the Amuri Bluff section, his Otapiri and Wairoa Formations (Triassic) extends from the coast at the Kahautara River across the Conway and Hurunui Rivers through the main mass of the Hawkswood Range, while the rocks exposed on both sides of the Waiau River are supposed to be of Maitai (Carboniferous) age. These latter rocks are the only part of the pre-Notocene series examined in any detail by the present writer, and any discussion of McKay's classification is beyond the scope of the present work. It may be noted, however, that his map is somewhat inaccurate regarding the areal distribution of the greywackes and associated shaly rocks which are exposed in the steep bluff where the Hawkswood Range is truncated by the sea some two miles to the north of the mouth of the Waiau River.

When the land was from 500 ft. to 900 ft. lower than now the Hawkswood Range determined the former shore-line with a wide, open bay to the north of the present bluff, which must then have had a considerable extension seaward. Emergence has exposed the local remnant of the Notocene "covering strata" in terraced flats filling the old embayment for a distance of 18 to 20 miles, and landward erosion of these younger beds has been interrupted by periodic renewals of uplift, and a more recent cycle of progradation near the mouth of the Conway River. The most striking feature of the present shore-line is that, although it formerly approached several times to or within a short distance of the arcuate base of the Hawkswood Range, it is now almost perfectly straight for a distance of some 18 miles from the Hawkswood Bluff to the mouth of the Okarahia Stream. The Notocene beds are divided into two very distinct localities by the Conway River—those to the north of it consisting of Cretaceous sands and sandstones overlain by the typical Amuri limestone and grey marl, while those to the south are only stratified gravels and massive conglomerates associated with sandy marls and sands all of a younger age. These localities will therefore be considered separately.

a. *North of the Conway River*: The Notocene rocks here form a narrow tilted strip lying close to the base of the pre-Notocene hills for a distance of some 7 miles and rising to a greater height in the eastern wing of the denuded anticline at Amuri Bluff. The sections exposed at the Amuri Bluff and in the north bank of the Conway both appear to be perfectly regular and undisturbed by faulting, and they both show a similar succession of sands and sandstones passing up into the Amuri limestone and grey marl. Haast (1871, pp. 37-39) described both sections in some detail and remarked (p. 39) on the complete disappearance of the Amuri Bluff beds in the southern bank of the river, they "being probably hidden under the large post-Pliocene shingle terraces which face the mountain sides, and which make their appearance again three miles south of the mouth of the Waiau-ua River, in a few cliffs washed by the surf."

In order to determine the relationship of the beds on either side of the river, continuous observations were made of the strike of the older Notocene beds exposed in the sea-cliffs from Amuri Bluff southwards. It is the strike of the Amuri limestone that is recorded, but this is discontinuous on the coast, it having sometimes been completely removed by marine erosion where the sea has cut through it at many points into the underlying sands. Indeed in one locality about a mile north of the Conway River the whole sequence of the Notocene beds has been removed, exposing the underlying Jurassic sandstone in the graded cliffs.

At Amuri Bluff, strike is N.E., dip S.E. 30°. (Speight and Wild, 1918, p. 87.)

At the mouth of the Okarahia Stream (just south), strike is N.E. (true). Here the beds are disturbed, dipping very steeply.

Farther south at cliffs from the face of which the limestone has lately been removed strike is N.E. (true).

Near the Boat Harbour, strike is N. 40° E. (true).

In reefs exposed at low tide near Claverly strike is N. 15° E. (true).

At first point below Claverly strike is N.S. (true).

In the Conway River section strike is N. 60° E. Dip southerly 45° to 50°.

This indicates the irregular nature of the outcrop and the manner in which it swings seawards from the mouth of the Okarahia Stream, and then inland to the south of Claverly, exposing the limestone in the north bank of the Conway at a considerable distance from the present shore-line. It appears highly probable, therefore, that the gravels and fossiliferous sands and sandy marls exposed in the high cliffs between the Conway River and the Hawkswood Bluff lie in their normal stratigraphical position.

South of the Conway River: In February, 1927, the writer examined the beds exposed in the cliffs between the Waiau and Conway Rivers, and on the return journey ascended the terraces in the southern and central portions of the Hawkswood area, and examined the beds exposed in the ravine-like valley of the Medina Creek. The return trip from the Conway to the Waiau occupies two days and should be undertaken only when the sea is calm and the tide low in the late afternoon and early morning, so that the base of the Hawkswood Bluff may be passed easily.

The coastal section from the Hawkswood Bluff to the lower terrace near the Conway River shows the following:—

a. Shaly greywacke exposed in the magnificent cliffs of the bluff. The rock is in places very shaly but becomes more massive farther north. It generally stands in an almost vertical position and shows considerable contortion.

b. Light grey sandy marls lying with sharp unconformity on (*a*), and dipping steeply in a direction a little to the north of east. The first exposure is seen two miles north of the Waiau River. In the first stream dissecting the main Hawkswood terrace they are seen for a distance of only 200 yards, ending abruptly against the shaly greywacke. They form the steep sea-cliffs from here to a point near the mouth of the Medina Creek.

c. Conglomerates of medium to coarse texture composed of well-rounded pebbles of greywacke and associated rocks. The cementing medium is highly ferruginous, imparting a rich coloration to the cliffs even where these are freshly exposed by slumping, which occurs here on a large scale. Very good sections through them are seen in the almost vertical walls of the narrow gorge at the mouth of the Medina Creek.

d. Sands. These succeed the conglomerates in the cliffs a little to the north of the Medina Creek. They are in places richly fossiliferous.

e. Gravels, less firmly cemented than (*d*), appear again about 5 miles south of the Conway River. These beds become increasingly finer in grain with alternating layers and lens shaped inclusions of brown, grey and yellow sands, until near Mr. D. MacFarlane's homestead they consist entirely of sand.

The section through Medina Creek shows a succession of (*a*) conglomerates, (*b*) sands and sandy marls, (*c*) conglomerates. There appear to be two bands of conglomerate, one near the shore-line, the other near the base of the Hawkswood Range, and separated by thick beds of fossiliferous sands and sandy marls. Closely similar beds are exposed in the lower Conway basin, and the examination of these will no doubt reveal their true stratigraphical position.

c. *Shore Platforms*: Various writers have referred to the presence of raised beaches in this locality. McKay (1886, p. 126; 1890A, p. 181) noted the occurrence of recent marine shells at Amuri Bluff at a height of 500 ft., but he did not think that the terraces on the seaward slope of the Hawkswood Range are a continuation of those between the Amuri Bluff and the Conway River. He no doubt referred to the larger of the terraces on either side of the river, the connection between these being certainly not very clear. Hutton (1877, p. 55, and section 12) referred to the Amuri Bluff and the Hawkswood terraces, and noted a higher terrace cut in the older rock south of the Conway at a height of 300 ft. It is apparent that Hutton's estimates of heights of terraces were always very conservative—in this case only a little more than half the actual height. Thomson (1912, p. 8) noted fossiliferous sandy beds in the valley of the Oaro Stream at 900 ft. It has been pointed out that these may belong to an earlier period than the raised beaches of the locality, but there is other evidence of cut platforms at about 1,000 ft. with which the deposits noted by Thomson may perhaps be correlated. Morgan (*loc. cit.*) notes further the occurrence of terraces at 40 ft., 50 ft., and 200 ft., near the mouth of the Conway, at 400 ft. near Claverly, and at 600 ft. above the Amuri Bluff.

As there seems no reasonable doubt that the terraces on both sides of the Conway are continuous, no distinction between the two areas will be made in the following description of shore-platforms at various levels:—

a. *At high-water mark*: Redistribution of fine gravel and sand from the material of the Waiau and Conway Rivers and of the receding portions of the coastal cliffs, has obscured the platform cut at present level, except in the neighbourhood of the Amuri Bluff. The reefs of limestone exposed at low tide near the Boat Harbour and Claverly (Haast, 1871, p. 38) form a remnant of a platform, the inner edge of which is thickly mantled with sand and shingle; but from the mouth of the Okarahia Stream, round the Bluff to Tarapuhi, the platform is singularly free from surface cover. Where the component rock is the grey marl, it has a very uniform level surface, except where the strike of the beds is parallel to the shore and their upturned edges project in a system of parallel ridges.

Here the junction between the grey marl and the Amuri limestone is very clearly shown (Speight and Wild, 1918, p. 87) and where the harder limestone forms the material of the platform, it has a highly irregular surface, with ragged unevenly-cut masses of rock extending for some 150 to 200 yards from the shore. The junction between the limestone and the underlying sandstone is also very clearly exposed at the north side of the bluff, and where this passes down into softer sands, the platform disappears under a mass of coarse gravel cast up on the beach. The surface is traversed by deep narrow channels developed from cracks similar to that which has been enlarged by wave-action into the natural arch at the end of the bluff. The large area of the platform exposed at low tide, and the manner in which it has become covered with beach deposits in other places suggest that recent slight uplift has taken place, but there is nothing to mark definitely the extent of it.

b. *At 30-40 ft.*: Just south of Claverly the base of the high cliffs retreats inland where the Notocene rocks have been completely removed at some points. This embayment of the former shore-line is in every respect similar to that which now exists to the south of Amuri Bluff, but it has been infilled with fine shingle and sand, attaining a maximum height of somewhat less than 40 ft., and forming the terraced area known as the lower Conway Flats. Distinct terraces, of the nature of successive barrier beaches, can be traced right across this lower plain; they are somewhat better developed on the north side of the river. The heights of these old barrier-beaches may be summarized as follows:—

Taking the top of the first bank of shingle on the shore (6 ft.) to be normal high-water mark,

The second terrace is 10 ft. above high-water mark.

The third terrace is about 22 ft. above high-water mark. (The inner edge of this terrace is not more than this height above high-water mark, and it is 25 to 30 chains wide.)

The fourth terrace is about 35 ft. above high-water mark. This terrace is of more limited extent and is found near the base of the cliffs just north of the Conway River.

The slope of all these terraces is definitely inland. It is difficult to form even a rough estimate of the actual amount of the elevation indicated by them. It is probable that the seaward edge of each shelf represents an old shingle barrier, which formerly enclosed a lagoon similar to that now existing at the mouth of the river.

c. *At 50-60 ft.*: In the extreme southern corner of the lower Conway Flat, Mr. D. Macfarlane's "Rafa Downs" homestead is built on a remnant of a higher platform at 50-60 ft. This height may not actually represent the level of a former beach, for it is uncertain to what extent it has been raised by material from the grading of the gravel cliffs behind it. In the low cliffs at the present shore-line the beds exposed are fine gravels, sands and clays containing remains of tree-trunks. This is probably the locality referred to by Buchanan (1868, p. 40, and section p. 38) who describes the finding of erect tree-trunks and stumps in position, in a tough blue clay overlain by sands and gravels exposed in the high cliffs. All the logs seen by the writer were prostrate, there being no erect stumps. Buchanan's section (p. 38) showing stumps in position cannot now be seen because the shore-platform depicted in the section is thickly covered with recent beach-shingle and sand. It is of course quite possible that this cover may have accumulated since 1866, but the few prostrate tree trunks now visible are not admissible evidence of recent local subsidence.

d. *At 150-160 ft.*: This is the height of the inner edge of the terrace at Amuri Bluff (South), where it shows a well-planed surface with terrace-gravels and sands resting with sharp unconformity on a basement of grey marl. Just north of the Conway River, however, there is a very steep rise from the rear of the lower flats to a height of 180-190 ft. Here the 150-160 ft. level is apparently not represented. It is well developed on the south bank of the river where, however, its surface relief has been modified by the river and by drainage tributary to the river. Just north of the "Rafa Downs" homestead, the terrace terminates abruptly in a gently-graded cliff rising to a platform about 90 ft. higher. The discontinuity of this terrace level through the Amuri Bluff-Hawkswood area is very confusing in correlating the various remnants but it is easily explained, for with the land 150 ft. lower than now, there would be large irregular embayments of the coast in striking contrast to the peculiarly straight line of the present shore. At Amuri Bluff the inner edge of the terrace is obscured by fan-like accumulation of angular chips of limestone from the hill above, and there is an abrupt rise to the terrace standing at about 550 ft. On the south bank of the Conway, too, there is a still more abrupt, almost precipitous rise to a terrace at the same level, though a little farther south a remnant of the 250 ft. platform is preserved.

e. *At 250 ft.*: On the north bank of the Conway River, the cliff (180 ft.) which determines the inner edge of the lower Flats is the present seaward margin of a gently-sloping terrace which, when traced along the left bank of Limestone Creek, rises to 220 ft., being about 30 ft. higher on the right bank. This terrace extends northwards until it merges gradually into the 150 ft. level near Amuri Bluff. It is well represented in the Hawkswood area where it extends as far south as Medina Creek. Here a terrace rises somewhat abruptly from it at a level of 330-370 ft., but it appears again in an extensive platform near the Hawkswood Bluff. The discontinuous fragments of this 250 ft. terrace, too, have the general shape of segments of circles, bearing witness to the embayed outline of the former shore. Although a general view of the area may give a confused idea of considerable surface-irregularity, the inner edges of terrace remnants at 250 ft. can be traced for long distances, and the boundaries of the old embayments thus fairly well defined. This, together with the accordance in level of the 250 ft. terrace at Kaikoura, indicates that elevation was remarkably regular for many miles.

f. *At 330-380 ft.*: As noted above this terrace is well represented just south of Medina Creek, and its inner edge rises to some 380 ft. Morgan (1916A, p. 24) estimated the height of the remnant behind the Claverly homestead to be 400 ft., and discontinuous remnants of ledges at 330-380 ft. occur throughout the Hawkswood area.

Terraces at this level appear to have been entirely removed from the seaward face of Amuri Bluff Hill and the hills immediately south of the Conway River. The remnants in the middle portion of the Hawkswood area are now little more than a succession of flat-topped spurs separated by narrow deep channels of consequent drainage, which make communication a matter of great difficulty. Though definite remnants of marine terraces at this level are notably absent near the Conway River, there are saddle-shaped fragments of river-terraces with abundant water-worn pebbles on the surface. These occur on both sides of the river at about a mile from its mouth. Here the stream bed is 30 ft., and the terraces 400 ft. above the sea.

g. *At 500-600 ft.*: It is difficult to define the exact level of the marine terrace represented by a very large number of fragments between these limits. McKay's estimate of the height of beds of fossiliferous beach-shingle and sand on the Amuri Bluff Hill was 500 ft., while Morgan (*loc. cit.*) records similar deposits at an estimated height of 600 ft. The highest point in this locality (Tarapuhi Trig. Station) is 583 ft. Hutton, also, recorded the height of the well-defined platform cut in sandstone above the Conway River as 300 ft. This is an extensive and remarkable ledge. Its seaward face is about 550-575 ft. and its inner edge stands at 800 ft. The extreme seaward face, immediately above the river, is accordant in height with the Amuri Bluff Hill, and with a number of levelled spurs with water-worn pebbles on their surface extending from the north bank of the Conway River past the seaward face of Mt. Guardian. Many fragments of an accordant height are found, too, extending far to the south of the river, and the continuity of the spurs levelled at this height is very clearly seen from the summit of the southern part of the Hawkswood Range. Probably the most reasonable estimate of the terrace level represented by all these fragments is 550 ft.

h. *At 650-700 ft.*: As noted above, the ledge above the Conway River observed by Hutton rises from 550 ft. to 800 ft. The writer is of opinion that a terrace-level occurs between these limits but has not sufficient evidence to say how far this is distributed through the area under discussion.

i. *At 800 ft.*: Widespread remnants of a terrace at this level occur for several miles to the south of the Conway River. The remnants are now nothing more than flat ledges cut in the spurs separating the parallel consequent stream valleys. High on the seaward face of the Hawkswood Range, they are not easy of access. For this reason the writer has measured them only on the bank of the river above referred to, near Medina Creek, and on the southern part of the range a little to the north of the Waiau River.

k. *At 1,000 ft.*: A well-defined ledge at about this level occurs immediately above the 800 ft. remnant at the Conway River. There appear to be corresponding ledges in several localities on the seaward face of the Hawkswood Range, though the writer is not prepared to say that they are all accordant in height. Also the deeply-dissected country in the neighbourhood of the Okarahia Stream and Oaro appears to have had formerly a levelled surface. This seems to have been observed by Thomson and Cotton (Thomson, 1912, p. 8), though the shells collected by them at about 900 ft. were contained in the Pliocene Hundalee Conglomerate, and not in a raised-beach deposit.

In the above discussion no pretence is made at completeness of treatment of an area which has hitherto received little attention, and which merits a more detailed survey. A very remarkably complete suite of marine terraces is preserved here, but correlation of the fragments and interpretation of the evidence has been made difficult by the discontinuity of the remnants throughout the area. Having found an explanation of this in the existence of former irregular embayments of the shore line, similar to that in which the material of the more recent lower Conway Flats has been deposited, more rapid progress was made in the work. Much remains to be done in examination of the higher level terraces to the south of the Conway River. Here the recently elevated terraced country is traversed by deep ravine-like channels of consequent drainage and much time is occupied in reaching any small part of the area where the higher terraces are developed.

I. THE HAWKSWOOD BLUFF TO THE BLYTH RIVER.

A large inland basin infilled with Tertiary marine beds extends from the fault-valley of the Greta, across the Hurunui, through Cheviot, Spotswood, and Parnassus to the Conway. "The structure of this basin is dominantly synclinal" (Speight, 1918, p. 98). A greywacke ridge separates it from the sea, and through it the Jed and the lower Waiau gorges have been cut. Speight (*loc. cit.*, p. 99) describes the nature of the syncline into which the Notocene beds have been folded at Gore Bay, and indicates the manner in which it is followed to the south by an anticline with a core of greywacke at the lower Hurunui Bridge. This greywacke appears to be in continuation of the ridge extending across the lower Waiau from Hawkswood to the Jed; it appears again on the coast at Port Robinson and in Manuka Bay at the seaward base of Mt. Seddon, and disappears under the covering strata immediately south of the Hurunui Bridge. Greywacke makes its last appearance on the North East Coast at the mouth of the Blyth River, but it can be traced as the core of an anticline as far as the main branch of the Motunau River at a distance of five miles from the sea. The strike of these pre-Notocene rocks and the direction of the ridge are variable and generally not parallel to the present shore. The regular alternation of the older and the younger sets of beds on the coast-line obtains as far south as the Blyth, this being the point at which the older rocks disappear from the coastal cliffs. From here southwards, however, a precisely similar regular alternation of the older and the younger members of the Notocene series is the most striking structural feature of the coast.

The nature of the Gore Bay syncline has been amply discussed by Haast (1871, p. 41 and section 16), Henderson (1918, pp. 171-4), Speight (1918, p. 99), and Speight and Jobberns (1928), and the stratigraphy at the mouth of the Hurunui has been described by Speight and Wild (1918, p. 80), and Speight and Jobberns (1928). Therefore little further reference to the structural features of these localities will be made in this paper, but a general description will be given of areas which have hitherto received little attention viz.:— (*a*) From Hawkswood Bluff to Gore Bay, and (*b*) from the Hurunui River to the Blyth. A correlation will then be made of the shore-platforms occurring on this part of the coast, indicating the very remarkable continuity and uniformity of former beach-levels.

a. *Hawkswood Bluff to Gore Bay*: In addition to the visit made to the mouth of the Waiau from the Conway, the writer also reached it along the coast-line from Gore Bay. Owing to the broken nature of the country, with its very steep rocky cliffs and boulder-strewn beach with impassable projecting bluffs, this trip, which was made in company with Mr. W. R. Robinson, proved very difficult. The waters of the Waiau formerly discharged into a small bay, filling it with fine shingle, sand, and silt, as exposed in the cliffed edges of the raised plain which now attains an average height of 40 ft. and covers an area of about 300 acres. The component material of the plain is in marked contrast to the coarser gravel now coming down the river to form the magnificent shingle-bank enclosing the lagoon at its mouth. Elsewhere high seas reach the base of the cliffs at almost all points between the Conway and Gore Bay.

Just south of the Waiau River mouth there is a small exposure of bluish-grey sand capped with dark yellowish gravels rising to 150 ft. About a quarter of a mile down the coast from the river, these sands show considerable distortion which has affected the overlying gravels as well, these being tilted very steeply from here to the first projecting bluff. At this bluff the ancient shaly sandstones are rendered almost schistose, and the beach is strewn with boulders of enormous size and masses of recent slip breccia consisting of fresh angular fragments. Just round the bluff to the south, the strike changes abruptly and the beds dip inland at a high angle, while from this point to the next bluff, which is impassable at the lowest tide, the rock changes to a more massive type of greywacke. When ascending this otherwise impassable bluff, the writer noted water-worn gravel on a fairly level surface at 370 ft. and again at 550-600 ft., while about half a mile below it are two very distinct gravel-capped remnants of a shore-platform at 350-400 ft. These are no doubt the terraces noted by Haast "three miles south of the Waiau-ua River" (1871, p. 39). From here to within about a mile of the Jed River the cliffs are very steep except where they have been graded somewhat by landslipping on an enormous scale. A characteristic feature of this slip-material is a hard re-cemented breccia consisting of sharp angular fragments of shale and sandstone imbedded in an earthy matrix of tenacious dark puggy clay produced by crushing of the shaly sandstones themselves. This material is somewhat resistant to wave-erosion and forms the material of a wave-cut platform on which are strewn irregular angular blocks and boulders of sandstone. This platform is more or less continuous along this coast, but its inner edge is obscured by angular debris from the cliffs and by shingle cast up to heights of 25 ft. in little bays. Some 2½ miles south of the Waiau River it is cut in a hard greywacke conglomerate with a very tenacious cementing-medium of dark-grey sand. Here, too, where the cliffs are more stable, are remnants of horizontally-stratified marine deposits 30-40 ft. thick lying on the planed surface of shaly sandstone at about 150 ft.

Some three miles north of the Jed River, near the site of the wreck of the "Tainui" is an enormous stack-like block of compact grey sandstone, separated from the shore by a rock-platform cut in the typical re-cemented sandstone breccia. It is sharply distinct from the softer material of the platform—i.e., entirely foreign to the rock in which it rests, and its is probable that it reached its present position at a time of unusually active slumping, evidence of which abounds here. On a base measuring 2 chains by 2 chains and tapering only slightly to a height of 60 ft., it is a remarkable feature of the shore. Near its base, at a level barely above normal high-water mark, is a wave-cut ledge similar to the high-water platforms described by Bartrum (1916, pp. 132-134). Between here and the Jed River also the cliffs show unusually active slumping of a somewhat incoherent brecciated material, and the whole coastal area resembles a wide shatter-belt suggestive of recent powerful faulting. But the continuity of reefs extending 300-400 yards off-shore, the general non-resistant nature of the shaly rocks which are tilted into a nearly vertical attitude, and the presence of undoubted remnants of what once must have been a continuous raised shore-platform, indicate that rapid recession of the cliffs by wave-attack combined with seaward slumping on a great scale might satisfactorily account for this very extraordinary type of coast. The brecciation of the rocks is no doubt largely due to faulting, but there is no convincing evidence of any recent movement on a big scale.

b. *From the Hurunui to the Blyth*: Speight (1918, p. 99) notes briefly the peculiar surface-features of this locality, but the only other reference to it is that of Hutton who says (1877, p. 55), "At the north head of the Blyth stratified shingle, resting unconformably on the Pareora formation forms hills 500 feet high." No reference is to be found in geological literature to the enormous development of older stratified gravels, occupying the lower basin of the Blyth for a distance of 5 miles from the sea, and covering an area of some 20 square miles.

The rocks exposed at the eastern base of Pendle Hill, where the Blyth River issues from a deep narrow gorge cut in greywacke, are sands and marls overlain by massive shelly conglomerates and sands (Mt. Brown beds). These pass up into sands and sandy marls with the hard "cement stone" inclusions of the Motunau series which, however, have only a limited exposure situated about 5 miles from the mouth of the river. Here on the left bank high bluffs are found to consist entirely of stratified gravels dipping south-easterly at 15°-20°, resting against the soft sands of the upper portion of the Mt. Brown series, and capped unconformably by thick beds of horizontally-stratified gravels attaining a height of over 500 ft. In the bed of the river below the bluffs the contact between the gravels and the Motunau beds is not visible, but from their relative positions their unconformity is evident. This exposure is of considerable importance as it removes doubts as to the Mt. Brown age of the sands with hard calcareous bands exposed at the mouth of the Hurunui River (Speight and Jobberns, 1928), and it enables the older gravels of the locality to be correlated definitely with the Kowai series of gravels (Speight, 1919, pp. 269-281) to which they bear a very close resemblance.

The sequence of Notocene rocks forming the south-easterly wing of the Hurunui Bridge anticline has been described elsewhere (Speight and Jobberns, 1928). Here the Mt. Brown beds lie unconformably on the grey marl and Amuri limestone, being themselves overlain unconformably by the older set of stratified gravels which, when traced southwards, are seen to have an enormous development. No doubt complete removal of the intervening Motunau beds and part of the upper Mt. Brown series preceded the deposition of the gravels in this locality. These gravels are well exposed in the cliffs just north of the Blyth, and magnificent sections through them are seen in the precipitous walls of the many ravine-like channels eroded here. The supply of waste, both as slip-debris from the cliffs, and water-borne shingle from these ravines, has far exceeded the capacity of the sea to remove it, so that an unusually wide strand-plain has developed in this locality. In these circumstances, however, it does not necessarily indicate any recent elevation.

On the south bank of the Blyth, near its mouth, the gravel-beds are seen to lie with sharp unconformity against the lower members of the Cretaceous series of sands and, where these disappear upstream, against the underlying greywacke which forms the core of the anticlinal ridge behind the Napenape beach. At the Hurunui Bridge, too, the greywacke and overlying Notocene beds involved in the anticline disappear abruptly beneath the gravels, and this anticline is at a much lower level than that of the Napenape ridge, and considerably out of alignment with it. Therefore the relation of the beds at the Hurunui Bridge to the similar beds at Napenape, and the relation of the gravels to the underlying rocks in the Blyth, together with their peculiar distribution and persistent south-easterly dip for several miles inland indicate that the valley of the Blyth has been determined by a fault with a considerable downthrow to the north-west. Since it is apparent that the gravels have not been involved in the movements affecting the underlying beds, it is very probable that their deposition proceeded after this faulting had taken place and the main structural features of the lower basin of the Blyth had been determined. The gravel-beds in contact with the greywacke on the south bank of the river have not been disturbed by faulting.

More recent movements have, however, profoundly affected the whole of the area. Prior to the deposition of the older gravels submergence of the eroded Notocene beds had accompanied the faulting above referred to, it being a most significant fact that the older gravel beds contain no fragments of rocks younger than greywacke. Therefore there seems very definite evidence here that the faulting, which was no doubt coincident with that which determined to a large extent the present physiography of Canterbury (Speight, 1915, pp. 336-353; 1926A, pp. 355-360), took place in the period intervening between the emergence and erosion of the Motunau beds and the deposition of the Kowai gravels. The subsequent history of the area has been one of general re-emergence with some slight warping of the surfaces planed by the sea, but with no appreciable renewal of the major faulting-movements. Speight (1919, p. 281) assigns a Pleistocene age to the Kowai gravels where these are unconformable to the Motunau series. Therefore the emergence of wave-terraced Kowai gravels indicates very clearly the Pleistocene or later age of this upward movement.

Beds of more or less horizontally stratified shingle and sand form a surface-cap on the planed edges of the underlying tilted strata, these later deposits extending far up the valley of the Blyth where Hutton (1877, p. 55) observed them overlying the Mt. Brown sands. In some places near the coast they attain a thickness of 50-60 feet and are not notably different in texture or material from the tilted gravels on which they lie. Such a thickness of surface-cover suggests deposition on a slightly sinking surface after planation of the older gravels had commenced. Then ensued the period of discontinuous uplift affecting the whole coast and leaving wave-cut terraces at 150-160 ft., 250 ft., 330-350 ft., and 525 ft. Speight (1918, p. 99) notes that the wave-levellel surface south of the Hurunui is higher near the coast than farther inland. The highest point near the coast is 525 ft., whereas, at a distance of 3 miles from the seas it is only 300 ft. This peculiar regular concavity of the surface must be attributed to warping, and the manner in which all the streams flow south-easterly to the Blyth has no doubt been determined by an original tilt in that direction.

CORRELATION OF SHORE-PLATFORMS.

While the nature of the later Tertiary deposits in the Blyth Valley affords some definite evidence of the age of the emergent coast, there is preserved in this area bordering the lower Hurunui a very complete record of the stages by which an elevation of at least 800-850 ft. has been attained. The locality deserves a more accurate survey of the heights of the terraces than the present writer has been able to make, a survey which would define clearly the number of periods of considerable standstill during the uplift process and the exact heights of the inner edges of the terrace remnants. There is no other part of the north-east coast with the exception of the lower Conway area where such accurate work could be undertaken to greater advantage. The following is a summary of the terraces preserved between the Waiau and the Blyth Rivers.

a. *High-water mark*: Rock-platforms cut at present sea-level are generally obscured by beach-drift. They are, however, well marked at Gore Bay and Port Robinson, and less distinctly on parts of the coast north of the Jed as described above.

b. *At 40-60 ft.*: Terraces at this level occur at the Waiau mouth and on the north bank of the Hurunui near its mouth. In the latter locality the terrace is cut in the Notocene beds below the bridge, and capped with a thin veneer of sand and fine gravel. Traced in a north-easterly direction it shows a gradual increase in height where the surface-cover is increased in thickness by alluvial material from the seaward slopes of Mt. Seddon. In Manuka Bay, a small rock-ledge cut in greywacke stands at 40 ft. and this probably represents the actual height of the cut portion of the platform.

c. *At 150-160 ft.*: A number of terrace-remnants at this level occur discontinuously. One has already been described from the Jed-Waiau coast and small rock-ledges on Mt. Seddon stand at 150 ft., probably the most reliable estimate of the height. This is also the approximate level of the lowest terrace cut in the Mt. Brown sands and Kowai gravels between the Hurunui and the Blyth, but the surface of this platform is uneven and, owing to irregular accumulation of debris from the incoherent gravels and sands of the more or less maturely graded cliff behind it, its inner edge is by no means horizontal.

d. *At 250 ft.*: The second terrace in the Hurunui-Blyth area stands at this level, and it is in every respect similar to the one immediately below it. In the southern part of Gore Bay the terrace, out of the soft gravelly sands and clays of which the well known "Cathedral" has been eroded, attains a maximum height of about 290 ft. But here, as elsewhere, the inner edge is obscured by accumulation of drift-material, and the actual height of the surface planed by the sea is probably only 250 ft. It may be traced southward to Port Robinson, where Henderson estimates its height as rising from 220 ft. to 250 ft. (1918, p. 174; 1924, p. 587). A remnant at 250 ft. is seen to the south of Port Robinson, in Manuka Bay, but here its inner edge is very uneven and it appears to grade into a lower platform at 150-160 ft.

e. *At 330-350 ft.*: Discontinuous fragments of a platform at this level are to be found on the Jed-Waiau coast (previously described), on the seaward slopes of Mt. Seddon and immediately south of the Hurunui. In the last-named locality the height of the terrace on the south bank of the river near the bridge is 300 ft., but it becomes higher when traced southward to the Blyth, where, however, its inner edge is not well defined.

f. *At 500-550 ft.*: Fragments of a platform cut in the greywacke of Mt. Seddon at nearly 550 ft. may be correlated with the maximum height (525 ft.) of the gravel-ridge south of the Hurunui Bridge. It is difficult to determine exactly the level of the standstill represented, but it lies within the limits of 500-550 ft.

g. *At 650 ft.*: Again on Mt. Seddon is a distinct bench cut in greywacke immediately above the Hurunui Bridge. Water-worn pebbles occur sparingly on its surface at 650 ft., but the origin of these is not certain. However, the occurrence of undoubted marine gravels at the summit of the hill strongly suggests that these too may have been beach-material, rather than river-shingle.

h. *At 800 ft.*: The Trig. Station (N) at the summit of Mt. Seddon stands at 784 ft. The surface is here thickly mantled with fine well-rounded pebbles and sands. That this is a beach-deposit may be accepted without any hesitation whatever, and it may be correlated with precisely similar material found above the Napenape cliffs at slightly over 800 ft.

The foregoing summary presents briefly the facts relating to a very complete series of terraces, and in it the writer has referred only to those remnants which preserve some admissible evidence of beach origin. Henderson, however (1918, p. 174; 1924, p. 586), refers to raised beaches at Gore Bay at 12 ft. and 80 ft. above present sea-level.

The conditions in the immediate vicinity of the Gore Bay syncline where immensely thick gravels are exposed in steep cliffs now some distance from the shore, are precisely similar to those obtaining just south of the Hurunui. Accumulation of unusual quantities of debris in a sheltered bay at the base of such cliffs might be expected even on a sinking shoreline. It must be noted too that the Jed River is to some extent tidal, and that the waves are vigorously attacking the cliffs where the thick gravel-beds have disappeared from the southeasterly wing of the syncline. In these circumstances it does not necessarily follow that the wide strand-plain in Gore Bay and extending to the northeast past the mouth of the Jed River is any indication at all of recent uplift.

It is immediately north of the mouth of the Jed that the terrace at approximately 80 ft. is developed. This has a flat surface of considerable extent and is separated sharply from the hills behind it by the deep channel of a stream which, rising near the summit of Mt. Maccoinnich has its lower course parallel to the present shore line—i.e., the stream does not enter the sea directly but is tributary to the lower Jed. The terrace has a distinct slope in accordance with the stream, and the sharp angular material with which it is thickly mantled is distinctly not beach-shingle. There is no marine platform with which it may be correlated and it must be regarded as a purely alluvial terrace, cut by the lateral swing of a stream which had deposited thick beds of angular debris at the foot of a steep slope. It does not necessarily indicate a period of standstill at 80 ft.

J. THE BLYTH RIVER TO AMBERLEY.

Throughout this area the following succession of rocks is exposed in the steep cliffs of the coast:—

a. Greywacke, in the cliffs at the mouth of the Blyth (south bank)—its last appearance on this coast.

b. Sands. Yellow sulphur sands, greensands, etc. (Cretaceous beds).

c. Amuri limestone, exposed in the cliffs at Napenape. In the south bluff at this point the top of the cliff is formed of the overlying grey marl, but it is the limestone which forms the lower cliffs for some distance to the south.

d. Grey marls, a greensandy facies characteristic of this locality.

e. Arenaceous shelly limestone, passing up into brown sands, with hard calcareous bands (Mt. Brown beds), exposed on the coast immediately northeast of Stonyhurst.

f. Grey marly sands, soft brown sands, with typical calcareous "cement stone" concretions and bands, and occasional bands of shelly conglomerate. These comprise the Motunau series, forming the basement rock of the Motunau Plain. They extent from Stonyhurst to a point some 3 miles south-west of the Motunau River.

g. Mt. Brown beds, a repetition of (e). They extend from the south-western extremity of the Motunau Plain to near the north-eastern base of Montserrat.

h. Grey marls. i. Amuri limestone. j. Sands (Cretaceous series).	All these beds are exposed on the seaward face of an eroded dome to the north-east of Montserrat.

k. Amuri limestone forms steep bluffs where the Montserrat ridge is cliffed by the sea. (Jobberns, 1926, p. 226).

l. Marls. m. Mt. Brown beds. n. Motunau beds. o. Mt. Brown beds.	These complete the succession of rocks exposed between the Montserrat ridge and the Waipara River near Amberley.

This remarkably regular alternation of beds within the Notocene series has an important bearing on the distribution of the fragments of raised shore-platforms. The greywacke no longer determines the inner edge of the raised platforms, its place being taken by limestones—i.e., the more resistant members of the Notocene series. Often the whole Notocene sequence is revealed in sections taken at right angles to the shoreline, and the harder limestones may stand out above the general level in simple homoclinal ridges forming the hills near the coast. The strike of the limestone shows a more or less regular variation imparting a gentle S shape to the outcrop. The general dip of the beds is south-easterly, at low angles where the limestone swings inland, but somewhat more steeply where it swings out to the present shore-line. A definite anticlinal dome-structure is developed immediately to the north-east of Montserrat, and the ridge forming the Napenape hills is a simple denuded anticline. In these areas raised shore-platforms have a restricted development, but the intervening Motunau Plain with a structure dominantly synclinal, is perhaps the most remarkable feature of the north-east coast. Similarly, while an excellent record of former beach-levels is preserved at Dovedale (Jobberns, 1926, pp. 225-26), similar continuous platforms are not found between there and the lower Waipara River, in an area where the Mt. Brown beds are folded into an anticline over Bills Hill as shown in the map accompanying Speight's description of that locality (1912, p. 223).

The Napenape Hills: These comprise the anticlinal ridge above referred to, extending from the mouth of the Blyth to Stonyhurst, and attaining a maximum height of 1,100 ft. in Sail Rock. The general direction of the greywacke forming the core of the ridge is indicated by its appearance in the coastal cliffs at the Blyth and again on the Stonyhurst road some three miles from the sea. The succession of beds exposed on the coast has been indicated above, and here they dip south-easterly at the moderate angles of 15-20 degrees. Above Napenape beach the summit of the ridge is formed of the Amuri limestone and on the inner face of the ridge it is seen to dip north-westerly. Speight and Wild (1918, p. 80) observed old shore-platforms here with beach-gravels at an estimated height of 500 ft. Henderson (1924, p. 587) correlated this level with the surface of "plateau like uplands" above Port Robinson, though the general level of the hill-tops in this locality is 800-850 ft. At this height the writer observed beds of well-rolled beach-shingle covering distinct benches cut in the limestone directly above Napenape beach.

Below the Napenape bluff a terrace with uneven surface and undefined inner edge stands at the 150-160 ft. level ending abruptly in limestone cliffs at the shore-line where there are several isolated stacks of the same rock. To the southwest the hills slope gently down to the Motunau Plain the inner edge of which is obscured by drift-material. South of this point the usual complete succession of wave-cut terraces is not well preserved, but a 350-400 ft. level is strikingly represented by the Motunau Plain.

The Motunau Plain: This remnant of a formerly very much more extensive plain of marine denudation is some 12 miles long, and attains a maximum width of about 2 miles in the vicinity of the Motunau River, it having the shape of a thin segment of a large circle. About 1¼ miles off-shore at the river-mouth is an island, of 5 acres in summit-area and unquestionably a remnant of a once larger plain (Speight, 1912, p. 224). Although this area had attracted the attention of Haast (1879, pp. 366-67), Hutton (1877, p. 54), McKay (1881, pp. 108-18; 1883, pp. 74-79), and Speight (1912, pp. 222-24), references to its physiography have hitherto been of a more or less casual nature, being included in observations made during the progress of other work. The discovery of recent marine shells and moa-bones on or near its surface gave an indication of its age, but it may be noted here that a considerable variation in estimates of its height recorded by various observers has led to confusion in interpretation of the nature and extent of the recent elevation. It was largely on account of the difficulties arising out of interpretation of its surface-features that the present writer found it advisable to make a more extended investigation of shore-platforms in other localities. The Motunau Plain, however, is of such large extent, and has all the characteristics of a raised beach so well preserved, that it could well be taken as a type with which any similar shore-platforms in other parts of the world might be compared.

Geological Structure: Sections through the complete series of Notocene beds exposed in the Motunau River and in Boundary Creek some two miles to the north, show the Amuri limestone and the harder parts of the overlying Mt. Brown beds, standing out high above the weathered surface of the softer sands to form the hills immediately behind the plain. Except where the beds are puckered into minor folds at Boundary Creek and again just south of the Motunau River, their dip is uniformly south-easterly at low angles decreasing steadily seawards. The hills therefore are of the nature of simple homoclinal ridges, with broad depressions behind them eroded out of the softer underlying sands. Through these coastal hills both these streams have cut deep narrow gorges, to cross the elevated plain in narrow channels deeply incised in the younger Motunau beds. Excellent sections are thereby exposed; and as no complete record of these has hitherto been published, that along the Motunau is here described in some detail. The section through Boundary Creek shows a very similar succession of rocks except that here the Amuri limestone has thinned out somewhat (Speight and Jobberns, 1928), and thin beds of coal occur at the base of the series (McKay, 1881, p. 111).

Section along the Motunau River Valley: For convenience of description these beds have been traced up the river from the mouth, and the sequence therefore is given in descending order.

a. Motunau beds: Compact, grey, argillaceous, well-cemented sands are exposed in the base of cliffs just north of the right bank of the river at its mouth. These beds are richly fossiliferous, and accessible only at low tide. They pass down into thick bands of very hard conglomerate, chiefly composed of fragments of oyster-shells. Below these are thick beds of friable yellowish sands exposed over a distance of nearly half a mile, where another band of very coarse shelly conglomerate forms a reef in the bed of the stream. Below this are yellowish sands passing down into soft sandy marls with hard cemented inclusions. These beds dip at about 12 S.S.E., the dip being a little flatter at the mouth of the river.

b. Mt. Brown beds: The above beds pass down without any apparent break into yellow and brown sands with hard calcareous bands and concretions. The actual contact between the two sets of beds cannot be distinguished. The calcareous bands in the sands become somewhat coarser in texture upstream, and the sands pass down into thick beds of arenaceous limestone interstratified with loose brown calcareous sands. Abundant shell remains show on the weathered surface of the limestone.

c. Marly greensands: 25 ft. thick. These are probably the local representative of the grey marls.

d. Amuri limestone with nodular layer (Speight and Wild, 1918, p. 81): The Amuri limestone forms a steep scarp above the river, and is traversed by a fault with a downthrow of some 80 ft. to the northwest. In the vicinity of the fault, extensive slipping has occurred, and the stream-bed is strewn with large angular blocks of limestone.

e. Shales and sands: These attain a considerable thickness in the depression behind the limestone escarpment. They are incoherent yellow and grey sands, passing down into,

f. Basal grits: In thin beds containing fragments of stems of Auraucarioxylon.

g. Greywacke: Forming a low ridge in the north bank of the river at a distance of 3 miles from the sea.

The marly greensands, limestone and underlying sands all dip a little south of S.E. at 20°. The Motunau beds at the river mouth dip at not more than 10°-12°. McKay (1881, p. 111) gives a section through Boundary Creek showing an unconformity between his Pareora and Mt. Brown series. In Boundary Creek the beds above the marly greensand are puckered into a syncline near the old ford, and the contact between the greensands and the Mt. Brown beds has been described elsewhere (Speight and Jobberns, 1928), but there is no evidence of unconformity above this junction. The regularity with which the dip of the upper beds decreases towards the coast is a feature characteristic of the Motunau area.

From the hills to the coastal cliffs, a distance of about 2½ miles, the planed edges of the Mt. Brown and Motunau beds are capped unconformably with gravels and fossilferous sands of recent origin. McKay (1881, p. 110) did not give much attention to these beds.

He stated, however, that the terrace-gravels gave no evidence of a marine origin. While it may be conceded that the beds capping the lower terraces within the stream-valleys are all of alluvial origin, marine deposits with scattered shell remains extend right back to the base of the stripped dip-slopes of the Mt. Brown beds above the Motunau gorge, at a height of 360 ft. The nature of these surface-beds is revealed in a section through them where they attain a thickness of 50 ft., in a high cliff (250 ft.), to the south-west of the mouth of the Motunau River. Here the following beds are exposed (in ascending order) :—

a. Sands, with greywacke pebbles.

b. Similar sands, with small well-rounded greywacke pebbles.

c. Limestone pebbles, flattened and of variable size, up to 4 in. in diameter. This bed has a variable thickness from 8 ft. to 20 ft.

d. Loose friable sands with scattered greywacke and limestone pebbles.

e. Clay, unstratified, unfossiliferous, not distinguishable from "loess" deposits, up to 30 ft. in thickness near the bank of the river.

f. Coarser beach-sands and pebbles with occasionally shell-fragments form a thin surface-veneer.

At various points nearer the mouth of the river and in the steep banks of some of the streams, the sands lying immediately on the planed edges of the basement Motunau beds are richly fossiliferous. The writer collected specimens from the cliffs above Motunau beach at 130 ft., from the cliffs on the north bank of the river up to 150 ft., and from the banks of streams north of the river up to 200 ft., Mr. E. W. Bennett, lately of the Canterbury Museum, found from examination of these that they were without exception recent species. Haast (1879, p. 367), and Hutton (1877, p. 54), noted the presence of these rich shell-beds, and McKay (1883, p. 74) excavated moa-bones from the surface deposits near Boundary Creek.

The Inner Edge of the Plain and the Old Sea Cliff: Although the inner edge of the plain is generally well defined, its surface is irregular, and precise measurement of the wave-levelled portion is a matter of some difficulty. Apart altogether from lack of uniformity of height due to irregular surface-accumulation at the base of the old cliff, a somewhat uneven elevation, probably due to warping, is obvious to the eye. The following is a summary of heights recorded from various points at the inner edge of the plain.

a. Remnants of platform in extreme south .... 400 ft.
b. Other remnants in vicinity, of variable height 350 ft.-400 ft.
c. Near the second stream south of Motunau River 400 ft.-450 ft.
d. South bank of Motunau River, above gorge ...... 350 ft.
e. North bank of Motunau River, above gorge ...... 360 ft.
f. A series of sub-parallel hummocky ridges between the Motunau River and Boundary Creek, stand above the general level at varying heights, viz.:—(1) 400 ft., (2) 375 ft., (3) 360 ft., (4) 390 ft., (5) 400 ft., (6) 410 ft., (7) 375 ft.
g. Immediately to the north of Boundary Creek, near the Happy Valley homestead, the average of several observations is 475 ft. In the middle of the plain a reservoir stands on a low hillock at 425 ft. It was from this locality that McKay

excavated moa-bones from an unusually thick surface-cover of recent beds, and it is highly probable that excessive progradation of the former shore-line was a factor in the raising of the inner surface of this part of the plain above the general level.

h. North of Black Birch Creek near Stonyhurst, the inner edge of the plain stands at approximately 400 ft., but here too it may be safely assumed that the actual height of the wave-levellel platform was somewhat lower than this.

As all this area near the Happy Valley homestead must have formed the head of a wide embayment of the former shore-line along-shore drift no doubt brought to it excessive quantities of waste and to these deposits were added the detritus from the subsequent grading of the cliffs, advancing irregularly in alluvial fans, and a certain amount of fine wind-blown sand. Unfortunately the only sections in which the nature of the deposits formed after retreat of the sea might be exposed are in the steep banks of the streams, but in these the streams have cut terraces of their own, and capped them with material of a fluvial nature. It is therefore impossible to determine exactly the height of the inner edge of the wave-levelled platform except at a few points, and it is equally impossible to determine what allowance is to be made for subsequent superficial deposit.

The grading of the cliffs at the rear of the plain has been determined in a very simple manner by the dip of the limestones forming the coastal hills. It is in the Motunau beds and the upper less resistant portion of the Mt. Brown series that the greater part of the platform was cut, the harder limestones then determining the outline of the shore, as they will again if the present cycle of marine erosion proceeds without interruption of further uplift. The actual inner edge of the platform is seen in the hard arenaceous Mt. Brown limestone in the north bank of the river at the gorge, and the manner in which the steeper slope of the cliffs has been reduced to that of these harder bands in the tilted Mt. Brown beds is very clearly shown. Stream channels have been cut back headwards into the rocks of the graded cliffs, but only a few streams have cut gorges right through the hills. However, in spite of this dissection of the dip-slopes the general outline and regularity of the old cliffs are still well preserved, furnishing further evidence of the comparatively juvenile age of the plain.

The Juvenile Drainage System: A peculiar surface of the Motunau Plain is a broad depression extending in a direction almost parallel to the present shore-line from a point near the Stonyhurst Road to the vicinity of the Motunau River which has cut its lower course across it. It is because of this depression that the coastal portion of the plain appears to be somewhat higher than the middle. It may represent a channel in the shore-platform eroded in the direction of prevailing currents in a manner similar to that which has formed between Motunau Island and the mainland. It seems more probable, however, that it is a channel of surface-drainage established shortly after the initial emergence of the platform. If this is so it implies that emergence was attended by warping resulting in a somewhat greater elevation in the north, this being supported, to some extent at least, by the manner in which the tributaries to the present stream almost without exception come in from that direction. Warping during uplift is also suggested by the fact that the Motunau River is tidal up to a point more than half a mile from its mouth, for it is difficult to imagine the capacity of this stream to erode its bed the necessary depth below high-water mark. Such warping, too, may account to some extent for the irregular nature of the inner edge of the platform as described above.

A sudden renewal of uplift, this being very rapid, brought about an abrupt change in drainage to the present system of parallel juvenile consequent streams, which have become deeply entrenched in the non-resistant basement-beds of the plain. Speight (1912, p. 224) describes briefly the character of these narrow gullies which dissect its surface, and by the precipitous nature of their walls make communication a matter of difficulty. Only those few which have cut gorges through the coastal hills are permanent in flow; some scarcely extend to the inner edge of the plain, while others are merely ravine-like gaps cut in the face of the cliffs.

One of the most remarkable of these smaller channels is the first to the south of the Motunau River, to which it was formerly a tributary when the land was some 160 ft. lower than now. Sea-erosion at the head of a small embayment has cut its course in two, and subsequent elevation has caused it to cut down to present sea-level in a trench with almost perpendicular sides and a width of less than two yards in its bed. The profile of the upper part of this channel shows two sharply distinct stages of cutting and the following indicates its nature precisely:—

Height of cliff at mouth	265 ft.
Width in bed	3 ft.
Width at top	66 ft.
Slope of walls, upper portion (1st cut)	45°
Slope of walls, lower portion (2nd cut)	75°-90°

This shows that a very steep valley has been eroded within an older valley with more maturely graded walls. The head of this channel is in the surface of the plain scarcely a mile from the sea, so that the grade cannot be less than 300 ft. to the mile. The Motunau River has terraced its banks in at least three distinct stages, but the terraces are not continuous downstream, and with them ledges due to intermittent lateral swing of the stream may be confused.

Boundary Creek, too, shows the nature of these narrow channels of recent incision in a very striking manner. Though the bed of the stream is somewhat more than 150 ft. above high-water mark at a distance of less than two miles from the sea, and the velocity of the flooded stream therefore very great, it follows a remarkably winding course in its bed. In the almost vertical walls of the valley the dip and strike of the beds appear to change abruptly at every turn, the actual dip being uniformly south-easterly at a low angle throughout the lower part of its course.

Despite the fact that in the surface of the plain evidence of pauses in the emergence process is not preserved, there is other evidence that the uplift by which the wave-levelled portion of the inner edge of the platform was raised to its present height of 350-400 ft. was intermittent. A pause at 150-160 ft. is sufficiently clearly indicated, while another at 250 ft. can reasonably be assumed from its regular occurrence in neighbouring localities. However, the most valuable evidence afforded by this area is that of quite recent emergence, as indicated by the remarkable features of a very juvenile drainage-system.

Marine Erosion and Motunau Island: Speight (1911, p. 224) states, " This plain of marine denudation once extended much farther seaward, and the small island at Motunau is a remnant of it, its flat top showing a marked alignment of its surface with that of the coast-line opposite. How far this plain extended seaward it is impossible to say at present, but at the mouth of the Waipara the river terraces appear high above the present level of the water, and are terminated suddenly when they reach the edge of the old marine cliff which marks the edge of the coastal plain."

Motunau Island appears to owe its preservation as a remnant of the plain entirely to the protection afforded to its base by a massive reef of conglomerate such as that exposed near the mouth of the river immediately opposite. It is situated 1¼ miles from the present shore, and the channel is not deep though the s.s. Ripple is reported to have passed through it at high tide dragging her anchor. This distance indicates a considerable rapidity of erosion of the non-resistant rocks at Motunau, there being further measurable evidence of its rate. In a landslip resulting from the earthquake of Christmas Day, 1922, an enormous mass of debris was piled up at the base of a bluff between the mouths of two stream channels. In a few months this had been completely removed by heavy seas, and some 3½ years later the writer observed that the cliff-base itself had receded some 18-20 ft. The late Mr. Byrch of Motunau Station informed the writer that he had observed erosion amounting to one chain in ten years, which would agree very well with that just noted. The protective effect of the hard conglomerate in the base of the cliffs just north of the river-mouth is seen in the very distinct projection of the coast-line at that point, but immediately opposite the Motunau Station homestead the cliffs are receding rapidly in spite of some accumulation of drift material at their base. The manner in which the island became isolated is indicated by a similar recession of the cliffs in the small bay south of the river, to the tidal portion of which the sea will ultimately cut its way and separate a block of considerable size from the mainland.

There can be no doubt that the plain formerly extended far beyond the outer edge of Motunau Island, and that its emergence belongs to quite recent geological time. In view of the rapid rate of cliff-recession observable here, however, there seems no need to suppose that any agency other than normal marine erosion has been responsible for its reduction to its present size. This question, having an important bearing on the present outline of the north-east coast, will be referred to subsequently in this paper.

Motunau Plain to Montserrat: In a previous paper (1926, pp. 225-26) the writer referred to the very abrupt change in the strike of the limestone of the Montserrat range as it swings round almost at right angles to continue through Vulcan Hill to the Motunau River. In the course of other work (Speight and Jobberns, 1928) the structure of a considerable portion of the adjacent country has been examined, and in the light of this further knowledge of the area it becomes more apparent how this abrupt change in direction of the limestone outcrop has had a profound effect on the topography of the coast. In the extreme south of the Motunau Plain the sandy marls typical of the locality pass down into Mt. Brown sands and limestones, and opposite the Mt. Vulcan homestead the underlying marls and Amuri limestone are exposed on the coast in a limited area which has suffered considerable disturbance and dislocation. Immediately behind the coastal ridge, of which the highest peak is Mt. Vulcan itself (Trig. P, 1,342 ft.), capped with a layer of Mt. Brown limestone dipping south-easterly at a low angle, is a broad valley eroded in sands of Cretaceous age. These sands form the core of a denuded anticline which terminates southwards at Montserrat, it being succeeded to the north-west by a corresponding syncline of which Montserrat and Oldham Peak in the Mt. Cass Range form the two wings (Speight and Jobberns, *loc. cit.*). On the coast at the point where the strike of the Notocene beds changes so abruptly is an immense landslip exposing the grey marly sands which here lie immediately below the Amuri limestone. This area of slip represents a large dome-like structure, which has collapsed where the steeply-dipping beds of limestone on its seaward face have been completely broken through. Immediately to the south the Amuri limestone attains a great thickness in Montserrat (1,492 ft.) and forms steep white cliffs on the coast-line. The structure of the Dovedale area is dominantly synclinal and here are preserved remnants of at least three distinct shore-platforms at 650-700 ft., 350 ft., and 250 ft. (Jobberns, 1926). On the face of the Montserrat dome described above, evidence of shore-platforms is not well preserved though the writer noted beach-shingle at 360 ft. and level surfaces at about 500 ft. In the broad floor of the valley eroded in the Mt. Vulcan anticline, a tributary of the Motunau River has carved a precipitous ravine nearly 150 ft. in depth, indicating recent abrupt elevation of that amount.

Montserrat-Amberley: The only addition the writer wishes to make to his published description of the Dovedale area, is to note the effect of very recent faulting on the shore-platform known as Bobs Flat. Though the inner edge of this platform is uneven, it attains an average height of 350 ft., and it is upwards of half a mile in width. Its seaward edge is remarkably straight, and it would appear that it is succeeded at a lower level by a platform of very irregular surface. Close examination of the surface marine beds of recent deposition shows that the platform has been traversed by a small and very recent fault with a downthrow amounting to approximately 120 ft. The subsidence of the downthrow block is somewhat irregular, and accounts for the uneven surface of the lower ledge. The fault scarp, however, is remarkably uniform and scarcely dissected at any point. This is the only locality on the north east coast in which recent faulting can actually be seen to have affected shore-line topography, the area involved being very small.

Shore-platforms to the south of the Dovedale area have all been cut in the Mt. Brown beds, which form the coast from here to the Waipara River. The writer has previously referred (1926) to terraces at 150-160 ft., and at 650-750 ft., and Speight (1912, p. 224) notes the existence of a remnant just north of the mouth of the Waipara River at 250 ft. This corresponds in height with a fragment in the Dovedale area. It appears, then, that although the evidence is necessarily fragmentary and discontinuous, terrace levels at approximately 150 ft., 250 ft., 350 ft., 500 ft., 650 ft., and 800 ft. persist throughout the whole length of the north-east coast from the White Bluffs near Blenheim to the mouth of the Waipara River, and at some points remnants of terraces at levels higher than 800 ft. are to be seen, though a good state of preservation of these is not to be expected. Remnants at lower levels, up to about 50 ft., also occur discontinuously, but wherever seen they are found to have resulted from brief pauses within the later (150 ft.) emergence.

The nature of the major structural features of the coastal country has been described in as much detail as has been considered necessary. The essential structural features of the lower Waipara area can be seen at once from the map accompanying Speight's description of that locality (1911). Here the Mt. Brown beds are seen to form a simple anticline over Bills Hill succeeding the syncline traversed by the road from the Waipara Railway Station to Dovedale. In North Canterbury, at least, it is very clearly seen that extensive shore-platforms are well preserved only at intervals on the coast, and that these represent the areas of which the structure is more or less synclinal. The writer would suggest tentatively that this may arise from a simple dome- and basin-structure, into which the Notocene beds have been folded, and which determines their present distribution on the coast—this structure being revealed where it is transected by the shore. No pretence is, however, made at completeness of treatment of coastal stratigraphy, which would demand far more time than the writer has been able to devote to the study. The remainder of the paper will be devoted to discussion of the possible effects of the emergent process on the Canterbury Plains and Banks Peninsula, and of certain theoretical questions which have necessarily arisen.

Part 2.

A. Gaps in the Evidence of Continuity of the Platforms, and the Fault Coast Hypothesis.

While the main purport of the foregoing part of this paper is description of the coast with special reference to shift of the strand, it becomes necessary to discuss various matters relating to similar phenomena recorded from other parts of the world. A great deal of the literature relating to post-Tertiary geology in Europe and America has not been accessible to the writer, but most of the relevant material available in this country has been consulted, including the comprehensive summary and synthesis of modern geological opinion on Quaternary geology made by Osborn and Reeds (1922, pp. 411-90).* No attempt will be made at correlation of the heights

*See also symposium on "Le Stratigraphie du Quaternaire" in 13 Session of Congrès geologique international, 1922, pp. 1409 and on (1926).

of terraces occurring on this part of the coast with those in other New Zealand localities—this already having been done, as far as is at present possible, by Henderson (1924, pp. 580-99). Before anything thoroughly satisfactory may be done in this respect many of the earlier and more casual estimates of terrace-levels occurring throughout our literature will have to be revised in the field. The possibility of correlation with terrace-levels in other parts of the world will, however, have to be considered, and in the light of recent advances in the knowledge of Quaternary geology in Europe and America, certain tentative suggestions will be made relating to our later Tertiary and post-Tertiary stratigraphy. Before these various matters are considered it will be necessary to discuss the possible effects of the emergence on the physiography of the Canterbury Plains and Banks Peninsula. At this stage, too, it is desirable to explain that though the writer has now become convinced of the continuity and uniformity of the process of emergence throughout the area extending from the White Bluffs to the Waipara River, there are certain gaps in the evidence which must not be overlooked. The absence of convincing evidence of high-level shore-platforms on portions of the coast, viz.:—*a.* Waipapa point to Maungamaumu Bay, and *b.* Kahautara River to Oaro Bay, has already been pointed out, these being two localities where the older rocks are exposed at the shore-line. With regard to the former, a well-defined cut platform at 10-15 ft. or more is almost continuous, and a platform cut at present sea-level is represented by extensive offshore reefs. These offshore reefs, too, are a feature of the Kahautara River-Oaro Bay coast, though here the cliffs are very fresh looking and more precipitous and a raised platform is not distinct.

Notwithstanding the unequivocal evidence of uplift preserved in the younger flanking rocks of the lower Clarence Valley, Kaikoura Peninsula, and Amuri Bluff, and the complete accordance in level of the terraces of the two latter localities at least, the absence of corresponding high-level terraces in the intervening areas is very marked. It cannot be due to any considerable extent to the resistance of the harder rocks to planing by the sea, because a succession of well-defined and extensive ledges has been cut in hard greywacke in other localities. Therefore it may perhaps be suggested that:—

a. The Lower Clarence, Kaikoura Peninsula, and Amuri Bluff areas have been elevated, while the intervening masses of older rock have remained stationary.

Or *b.* The apparently unterraced blocks have subsided after a general uniform elevation.

Or *c.* Post Kaikoura faulting with subsidence to complete submergence of the seaward portions of two entirely distinct blocks has drowned the evidence of any terracing that there may have been. Elevation on the landward side only of a coastal fault-line would have the same effect.

It may be admitted that any of these explanations is possible but (*a*) and (*b*), implying such sharply differential vertical movement of adjacent earth blocks, are at least very unlikely, and are unsupported by any visible evidence from the field. In this connection it is most important to recall that in the almost precisely similar

Hawkswood Bluff-Gore Bay area, there are only small fragments of raised beaches more or less fortuitously preserved, but sufficient to prove definitely that the terraces of the Conway are to be correlated with those of the Hurunui, and that more or less uniform uplift was continuous from the Waipara River to Amuri Bluff. Further, the accordance in level of the terraces of Kaikoura Peninsula and the Amuri Bluff is so remarkable, that it becomes almost inconceivable that these places emerged to their present height by a movement which left the intervening coast unaffected, or that this latter block of older rocks was subjected to any subsidence which drowned a face terraced at corresponding levels. Admittedly there is evidence of disturbance by faulting at Oaro, but the Notocene beds, involved in the syncline succeeding the Amuri Bluff anticline, lie against the Greywacke block and show no sign of the extensive dislocation such a differential movement would demand.

There remains the alternative of the fault-coast hypothesis which has been put forward by Cotton (1916A, pp. 20-47), but which on examination in the field is found to be unsatisfactory, in some respects. The present writer, however, being concerned with the hypothesis only insofar as it may affect the continuity of the coastal platforms, does not propose to traverse it in detail.

South of Kaikoura Cotton sees a "young one cycle fault coast." The conception of a huge cauldron-like subsidence of the sea-floor seems to accord very well with the occurrence of deep water close inshore, and with the general appearance of the cliffs on the coast, and an easy way out of the difficulty would be to suggest that such downward movement occurred late in Quaternary time to an extent sufficient to submerge any portion which may have been terraced in accordance with Kaikoura Peninsula and Amuri Bluff. The present writer, however, has found no more tangible evidence to suggest such extensive faulting later than the main Kaikoura orogeny, though it is well known that many of the Marlborough faults are still alive, and this orogeny may perhaps be considered to be still in progress.

For the establishment of an "hypothesis of regional uplift following faulting," north of Kaikoura, Cotton attaches considerable importance to the fact that the so-called "Clarence Delta" was "built out upon the seaward block"—i.e., across the line of the hypothetical fault which had predetermined the line of the coast. This idea seems to have been based on a misconception of the structure of the "delta," and certainly on a misconception of the age of its component gravel-beds. Three miles from the sea these gravels are involved in a great reversed fault which must belong to the Kaikoura orogeny, and if the marl-beds at Otu Kaku Point—i.e., the extreme seaward point of the northern half of the "delta"—are equivalent in age to the "greymarls" of Deadmans Creek, then the gravels of the "delta" may be regarded as equivalent in age to the Great Marlborough Conglomerate.

Further, any such fault-coast hypothesis is faced with the problem of explaining the existence of the Kaikoura Peninsula in its present position; but since here the regional uplift is considered to have post-dated the faulting, the question of the possible removal of terraces does not arise. Cotton met the difficulty by supposing that the subsidence of the seaward block has been differential and that it stopped short of Kaikoura Peninsula. Whether this was the case or not, there is a close accordance in level between the terraced summit of the Peninsula and remnants of shore-platforms and river-terraces in the Clarence-Kekerangu area. On this part of the coast, too, it does not seem reasonable to suppose that these areas emerged as the result of an uplift which left the intervening greywacke block unaffected. This participated at least in the most recent stage of the emergence.

While discussing the fault-coast hypothesis, however, it may be remarked that Cotton appears unable to credit the capacity of the sea to erode the coast until only fragments of shore-platforms and river-terraces (at 500 ft.) remain. The rate of erosion is measurable at Motunau, and must have been prodigious at Kaikoura, as also on almost the entire length of the coast, where offshore reefs are widely distributed and extend far out to sea. Taking into consideration the generally non-resistant nature of the rocks concerned, and the strong probability that the shore was similarly cliffed by erosion when the general level of the land was considerably *higher* than now, this difficulty is largely removed.

He suggests further that the transection of the harder and softer rocks by the present straight shore-line is strong evidence in favour of the hypothesis; but it will most probably be found that this alternation of harder and softer rocks is a simple structural feature of the coast, and that while the major platforms cut in the softer rocks in ancient embayments have generally been reduced to fragments, those of much lesser extent cut in the protruding faces of the harder rocks have been removed completely. At a time when the land was some 500 ft. lower than now, the shore-line was gently sinuous with quite pronounced salients of harder rock, as it will be again if erosion at present sea-level proceeds without interruption.

B. THE CANTERBURY PLAINS.

The general nature and essential structural features of these plains have been surveyed elsewhere (Jobberns, 1927, pp. 88-96). In that brief summary the writer put forward the views of Haast (1863, pp. 1-63, 1879, pp. 396-406) and further elaborated by Speight (1908, pp. 16-43; 1911A, pp. 420-436; 1911B, pp. 408-20; 1917B, pp. 361-364; 1926B, pp. 363-368), views which will be somewhat modified in this paper. Hutton (1884, pp. 449-54; 1877, pp. 56-58; 1905, pp. 465-72) maintained always that the present surface of the plains was produced by the levelling of the sea—but nowhere, except on their extreme outer margin is there any visible tangible sign of a former strand-line. All the gravels exposed in the high terraced banks of the upper valleys of the large rivers like the Waimakariri, Rakaia, Ashburton, and Rangitata appear to be entirely alluvial in origin, and the succession of wide arched ridges and corresponding depressions typical of alluvial fan-structure is complete. It is a structural feature that an accurate contour-survey of the surface would only show more clearly. Speight, too (1908), gives an extremely lucid and apparently altogether satisfactory account of the terraces so well developed in the major rivers, stating that they are entirely due to the terracing of alluvial fans when decrease in the supply of waste to the rivers enlarged their capacity to cut.

In spite of this, however, it is inconceivable to the present writer that the movement of emergence so distinct, continuous, and equable extending from White Bluffs to the Waipara River, ended abruptly near the northern edge of the Canterbury Plains. Hutton's opinion will therefore have to be reviewed, but it is equally inconceivable that the present surface features of the plains—i.e., the perfectly regular succession of alluvial fans with corresponding inter-fan depressions—were produced by the waves of the sea. Mr. H. W. Harris, Resident Engineer to the Waimakariri River Trust, recently called the writer's attention to abnormal accumulation of shingle in the bed of the Waimakariri immediately below White's Bridge, at a point where the grade of the river is not more than two feet per mile, and where hitherto sand was the only deposit in the bed of the stream. The shingle-advance, dating from a moderate flood of 1926, has piled up a large bank of material across the river—material containing pebbles up to 4 inches in diameter. In the immediate neighbourhood is a deposit of small well-rolled pebbles of beach-shingle with shells, situated some 4 miles from the shore and at a height of 8 feet above sea-level. Therefore on the narrow coastal strip fringing the plain, where the grade is only about 2 feet per mile over a width of 4 miles, coarse shingle can now be seen advancing downstream, and it can be imagined that this might in the course of time completely obliterate the fragmentary traces of a former strand-line preserved here. Conditions are not quite the same, however, as they must have been formerly, for since the joining on of Banks Peninsula to the mainland with the consequent deflection of the powerful northerly current round the Peninsula, progradation by the sea has greatly increased the width of the fringing plain in this locality.

Whether the present abnormal drift of shingle downstream is due to increased supply from the mountains or to lateral cutting of the terraced gravel-banks in the higher plains may be a matter of dispute, but it is unimportant here. The capacity of the river to obliterate traces of the sea is demonstrable, and it becomes reasonable to assume that although no part of the present surface of the higher plains was ever washed by the sea, and all the gravel exposed in the terraced banks 400 ft. high (where the plain surface is about 1,000 ft.) may be entirely alluvial, the gravel under-structure of the plains emerged from the sea in harmony with the coast to the northward. The emergence itself would entail vast increase in the supply of waste to the already overloaded streams, and the advancing fans may never have been cliffed to any extent if at all.

The thickness of the gravels comprising the plains is immense, nearly 2,000 ft. being penetrated by the Chertsey bore without contact with the underlying solid rock. Chertsey, however, is some 380 ft. above sea-level at a distance of 12 miles from the shore, and it is here that the alluvial fan-structure is most clearly shown—the enormous fan of the combined Rakaia-Ashburton being transected by the shore-line in steep cliffs upwards of 100 ft. in height. Henderson, however, notes (1922, p. 12; 1924, p. 593) that below 1,500 ft. of gravels are oxidized sands and clays to 1,800 ft. below sea-level, quoting this as evidence of depression. That the land was depressed far below a former level is indicated by the topography of Banks Peninsula, but its re-emergence must have been more or less in harmony with that of the rest of the coast to the north.

The writer has made no examination of the terraces of the major Canterbury rivers and therefore does not know whether there is any close correlation to be made between them and the raised shore-platforms. That they appear to be cut in entirely fluvial material need not affect the general conception of the re-emergence of the plains in stages corresponding to those recorded from the immediately adjacent north-east coast.

Extending from the mouth of the Waipara River to the neighbourhood of Saltwater Creek is a marine terrace at a comparatively low height, already described by Speight (1912, p. 222, and map p. 223), and Jobberns (1926, p. 226). Its undulating surface, covered with sand dunes in the south, ranges in height from scarcely above sea-level in certain swampy areas to about 30-35 ft. near the base of the low cliffs behind it. To estimate the amount of Recent uplift it actually represents is exceedingly difficult, for much of it is no doubt due to simple progradation arising from alongshore drift of alluvial sand and shingle from the Ashley, Kowhai, and Waipara Rivers. The writer, however, recently excavated the semi-fossilized base of a skull of a large whale from the bed of the Kowhai River some two miles from the sea near the base of the cliffs, at an estimated height of 20 ft. above present high-water mark. The low cliffs disappear to the southward near Saltwater Creek, but this does not necessarily indicate decrease in amount of recent emergence in that direction; for as Daly (1920, p. 250) remarks, "along young coastal plains, sea cliffing might not have taken place systematically at all." As noted above, undoubted marine grits occur near Whites Bridge at the Waimakariri, as they do also just north of Kaiapoi near the Main North Road, being in both places about 8 ft. above sea-level. It must be observed, however, that both the Waimakariri and Saltwater Creek are tidal streams. The former was probably capable of eroding its bed in the lowland fringing the shore, somewhat below high-water mark, this being less likely in the case of the latter. Saltwater Creek has silted up considerably in recent years, but this may perhaps have attended settlement and cultivation of the land. The amount of recent emergence becomes definitely measurable again at Redcliffs and Sumner, where it amounts to 15 ft. above high-water mark. To say that a raised strand-plain extended from the mouth of the Waipara River to Sumner is perfectly reasonable, but whether its emergence was uniform cannot be known. The nature of the lower courses of the Waimakariri and Saltwater Creek suggest irregularity.

C. BANKS PENINSLUA.

The recent emergence of 15-20 ft. referred to above did much to complete the joining on of Banks Peninsula to the mainland.

Haast (1863, pp. 49, 52; 1879, p. 367) recorded evidence of raised beaches at Sumner, and on the south side of the Peninsula, and the writer has noted caves with finely stratified clay up to 15 ft. at McCormick Bay, caves with shells embedded in stratified clay at the north end of Sumner township, and at Monck Cave in Redcliffs; and caves at the base of cliffs now far removed from the sea and definitely above high-water mark in many other parts of Redcliffs and Sumner. The wide plain on which Redcliffs township is built, and the plain filling Sumner Valley, however, were no doubt formed largely of sand drifting down with the current from the Waimakariri, and the extent or present surface-height of these is by no means necessarily a measure of recent elevation of the land. This progradation combined with a slight elevation of the land effected the filling in of a shallow sea and the junction of Banks Peninsula to the mainland quite late in Quaternary time.

The present topography of Banks Peninsula indicates enormous dissection of the land when deep valleys were cut in the resistant volcanic rock in all parts except on the immaturely dissected slopes of Mt. Herbert. The land must formerly have stood at a much higher level, the evidence for which has been summarized by Speight (1917A, pp. 385-7). Drowning of the river-valleys and submergence of the calderas of Lyttelton and Akaroa resulted from subsequent depression. For the reasons here stated, the present writer believes that this depression was to a level at least some 800 ft. lower than now, and that subsequent emergence has only partially restored the land to its former level.

a. From Table Mountain at the head of Charteris Bay, a narrow tongue of land terminating in Potts Peninsula runs out into Lyttelton Harbour. This shows a succession of rocks from the basal sandstones through several types of rhyolite to the fine grained basalt of Mt. Herbert. The inner edge of this is an almost perfectly flat surface of considerable summit-area, rising gently to the steeply cliffed face of Table Mountain. This level surface at about 800 ft. is perfectly accordant in level with similar flat surfaces on either side of Gebbie Pass, by which Lyttelton Harbour is now separated from Lake Ellesmere. Though apparently complete absence of ordinary beach-material from these levels must be admitted, no other explanation seems possible than to assume that they represent remnants of a wave-cut surface formed at a time when the sea divided the island into two separate parts. When Gebbie Pass was submerged the northerly currents would sweep through here, and it is most improbable that any water-worn pebbles of the constituent rock of the island would be retained on the cut platform.

b. The foreland on which the Godley Head Lighthouse is situated has an almost perfectly levelled surface rising gently inland from 450 ft. to 475 ft. or a little higher. Speight (1908, p. 32) has previously referred to this as a surface possibly produced by marine erosion. It may be suggested that the absence of a definite cliff behind it is an objection to this view of its origin, but the erosion of gently-sloping flows of lava over a comparatively short period might not necessarily result in cliffing. For the same reason it is somewhat difficult to estimate the exact level of a period of standstill in which it was produced. It was probably of 475-500 ft. Levelled spurs of accordant height are seen on the opposite side of the harbour entrance at Port Levy.

In accordance with this level are several large caves at a height of about 500 ft. above the sea in the head of the valley above the Redcliffs Rifle Range. One of these is very large, and one is definitely an ancient blowhole. On the floors of all are abundant shell-remains, but these serve only as evidence of former Maori occupation of them.

c. Scarborough, above Sumner Head or Whitewash Head, is a similarly-levelled spur standing at the lower level of 350 ft. Its surface is remarkably uniform, and there can be little reasonable doubt that the general regular emergence of the coast extended to this point as well. It should be noted, too, that the majority of the spur-ends between Port Levy and Long Lookout Point are definitely flattened at about this level.

It has prevously been suggested (Speight, *loc. cit.*) that certain of these levelled spur-ends may be admissible evidence of former submergence of the land to their level, but the writer cannot but believe that they correspond more or less completely to the shore-platforms from other parts of the coast, and that a thorough examination of the Peninsula and correlation of the levels from different localities will prove this beyond doubt.

D. A CORRELATION WITH SOUTH EUROPEAN PLATFORMS.

Converting the heights of marine terraces recorded from Western Mediterranean coasts by de Lamothe and quoted by Osborn and Reeds (1922, p. 423) into feet, for the purpose of comparison with those determined on the north-east coast of the South Island by the present writer, we have the table of comparison given herein. The writer desires to point out, however, that it was not until some time after most of the field-work for this paper was completed that any possibility of close correlation with the terraces of Europe or elsewhere was considered, and that therefore no attempt has been made in the field to see how far the heights of the European terraces apply to those of New Zealand. The results of the writer's investigations were arrived at quite independently, and all that is now being done is to set them out for comparison with the levels recorded by de Lamothe. Also, while the heights of the terraces have been defined within comparison narrow limits by de Lamothe, this has been impossible with the methods employed by the present writer. For this paper, the measurement of heights lower than 50 ft. has been made from normal high-water mark with the Abney level, while for greater heights the measurements recorded are all barometric. Two Aneroid barometers were used, these having been adjusted to the standard barometer in the Christchurch Observatory over a considerable period. Since inaccuracies may arise with the most careful use of the barometer, and since it has generally been found difficult to determine exactly the position of the inner edge of the wave-levelled portion of terraces, the writer has often not defined their heights locally within 50 ft. or so. With this explanation, a table of comparison with Western Mediterranean levels is given below.

New Zealand (South Island). (Jobberns).		Mediterranean. (de Lamothe).
a. 40- 60 ft.	Pleistocene or Quaternary	60-66 ft. (Monastirian Stage).
b. 120-150 ft.		92-98 ft. (Tyrrhenian Stage).
c. 230-250 ft.		181-198 ft. (Milazzian Stage).
d. 330-380 ft.		295-328 ft. (Sicilian Stage).
e. 500-525 ft.	Pliocene?	486 ft.
f. 650-700 ft.		670 ft.
g. 800-900 ft		870 ft.
h 1000-1200 ft. (estimated)		1075 ft.

In the section of the New Zealand coast under discussion the highest level (*h*) is represented by the even sky-line of the summit of the Vernon Range (Cotton, 1914, Fig. 3, p. 288) and by the higher terraces in the Hawkswood area. If this even sky-line is shown to be the result of wave-levelling, then 1,000-1,200 ft. is only a rough estimate of the level of standstill represented. Apart from this, however, the correspondence in the number of sufficiently well-defined stages in the emergence of this part of the New Zealand coast with those recognized in the Western Mediterranean is exact. There is also a fairly close accordance in the heights of the terraces representing each stage, an accordance, however, which will probably not prove to be much more exact from the use of more precise methods of measurement. It is the definition of the inner margins of the terrace-fragments to be measured which presents the greater difficulty in accurate observation of this New Zealand coast. Furthermore, the variation in height can be shown to be due, to some extent at least, to local irregularity of uplift. So even with the most precise methods of measurement of heights, they cannot be defined within the narrow limits assigned to those of Europe, and if their uplift is not simply eustatic this is not to be expected.

E. A CORRELATION WITH SOUTH AMERICAN PLATFORMS.

A remarkable parallel to the later emergence of New Zealand is to be found in Darwin's account of the geology of South America written nearly a century ago. From his investigation of both the eastern and western shores of the continent he found abundant material which bears a close resemblance to that just described from this comparatively small section of the New Zealand coast. With a minimum of speculation as to probable cause, he records the traces of the emergence in precise measurement of the present heights of former beach-levels extending through several degrees of latitude, and though the area examined by the present writer comprises some 2½ degrees of latitude only, the number of pauses in the elevatory process and the present heights of the corresponding terrace remnants agree very closely with the data collected by Darwin within approximately similar latitudes on the other side of the Pacific.

His stated object in recording precisely the elevation of the terraces, the marine origin of which was generally indicated unequivocally by the abundance of Recent shells in surface deposits was, "To show the remarkable equability of the recent elevatory movement." He notes, further, "The extension of the 330-350 ft. plain is very striking, being found over a space of 500 geographical miles in a north and south line." Then follows a summary of terraces occurring at this level, extending from the Gallegos River to New Bay—i.e., throughout latitudes 43° S. to 52° S. There is a similar record of terraces within the 200-300 ft. limit (generally 250 ft. where measured height is recorded), ranging from Coy Inlet to Bahia Blanca—i.e., through latitudes 39° S. to 51° S. "The extension moreover of the 560 to 580 and of the 80 to 100 ft. plain is remarkable, though somewhat less obvious than in the former cases. Bearing in mind that I have not picked these measurements out of a series, but have used all those which represented the edges of plains I think it scarcely possible that these coincidence in height should be accidental. We must therefore conclude that the action, whatever it may have been, by which these plains have been modelled into their present forms, has been singularly uniform."

He records, too, a plain at 840 ft. at the mouth of the Santa Cruz, "extending horizontally far to the south." "On the three lower ones, namely, those of 100 ft., 250 ft., and 350 ft. in height, existing littoral shells are abundantly strewed, either on the surface, or partially embedded in the superficial sandy earth. By whatever action these three lower plains have been modelled, so undoubtedly have all the higher ones, up to a height of 950 ft. at S. Julian and of 1,200 ft. (by estimation) along St. Georges Bay."

In order to avoid unduly lengthy reference to Darwin's account of the western coast of South America, the island of Chiloe may be taken as typical, it lying almost exactly within the same limits of latitude as the part of the New Zealand coast under discussion. Here he records quite recent elevation up to 10 ft., and immense shell-beds on a tableland at 350 ft. Also near Castro, "three distinct terraces are seen; the lowest was estimated at about one hundred and fifty feet in height, and the highest at about five hundred feet, with the country irregularly rising behind it; obscure traces, also, of these same terraces could be seen along other parts of the coast."

Except that the terrace at 80-100 ft. developed on the eastern coast of South America is represented in our New Zealand area by one at 120-150 ft., the correspondence between the various levels is most extraordinary. It is, in fact, the most striking coincidence encountered by the present writer in the literature consulted on the subject, and there is an equally striking coincidence in the latitude of the areas involved.

The table of correlation of terrace levels may therefore be extended as follows. In adition to the levels set out in it for comparison, a terrace of Recent emergence and attaining a height of only a few feet has been recorded from all of these localities. It is a curious fact that such well-developed terraces in this extensive series have been recorded from comparatively restricted areas, but in the absence of any definite statements that the *series* is not developed on coasts nearer to the equator, it can only be suggested that latitude is a factor determining their distribution.

New Zealand. (Jobberns).	South Europe. (de Lamothe).	South America. (Darwin).
a. 40— 60 ft.	60— 66 ft.	No record.
b. 120—150 ft.	92— 98 ft.	80—100 ft.
c. 230—250 ft.	181—198 ft.	200—250 ft.
d. 330—380 ft.	295—328 ft.	330—350 ft.
e. 500—525 ft.	486 ft.	500—580 ft.
f. 650—700 ft.	670 ft.	No record.
g. 800—900 ft.	870 ft.	840 ft.
h. 1000-1200 ft. (estimated).	1075 ft.	950 ft.
		1200 ft. (estimated).

[Since this paper went to the printer, the writer has received, by the courtesy of Dr. A. V. Krige, a copy of his paper on changes of sea-level in South Africa (1927), a review of which appeared in the Geological Magazine of May 1928. Much of Krige's paper is concerned with the recording of data relative to the last stage in the process of emergence—*i.e.* the 20 ft. beach which is found over a wide area in South Africa. He has also abundant evidence of the existence of a beach at 50-60 ft., but he has not defined the heights of the higher terraces noted within narrower limits than 100 ft. or so, and his paper therefore does not indicate whether there is enough evidence in South Africa for a correlation of the upper terraces with those of New Zealand, South America, and Europe—a correlation which might have been expected if they are really a function of latitude as has been suggested by the present writer. It is important to note, however, that Krige sees evidence of depression (submerged river-valleys) existing side by side with evidence of elevation. He also records the existence of submerged ledges on the Agulhas Bank in an area where the 20 ft. and the 50-60 ft. raised beaches, at least, are strikingly developed. All this suggests strongly that in South Africa as in New Zealand the level of the land was probably considerably higher than now, but there does not yet seem to be available anywhere sufficient evidence to assign a cause to the vertical movements of the shore-line which seem to have been remarkably regular in widely separated localities.

Krige follows Daly in offering a simple eustatic explanation of the emergence of the lower terraces, particularly the 20 ft. beach. There may indeed have been a eustatic negative shift of sea-level world-wide in its effects, but it is only the last visible incident in a series of changes which the eustatic hypothesis in itself seems not competent to explain. The withdrawal of sea-water to form the Pleistocene ice of the higher latitudes might conceivably result in the exposure of a terraced Agulhas Bank which would be drowned again on the return of the water to the sea. But this certainly does not and can not explain the existence of raised beaches in Europe, South America, and New Zealand, for if so, these should not form a regular suite extending to hundreds of feet *above* the present shore-line, but should be in the position of the submarine ledges of the Agulhas Bank, submerged by the return to the sea of the water from the melting of the Pleistocene ice-caps.

Where evidence of depression exists side by side with evidence of elevation, the differential vertical movement of adjacent earth-blocks at once suggests itself as an explanation (as in the case of the "downthrown block" of the Marlborough Sounds), but there may, after all, be no necessity to suppose this to be always the case. Eustatic movements of ocean-level resulting from the loading of the Polar regions with ice might expose terraced shores only to drown them again as the ice melted. Therefore the level of the land in the areas exhibiting the higher shore-terraces must also have changed, quite apart from these eustatic fluctuations of sea-level, and it is possible that this too may have been connected with the excessive loading of the higher latitudes in Pleistocene times. In this connection two simple hypotheses suggest themselves, though there is at present little enough evidence to justify them.

a. The loading of the Polar regions with Pleistocene ice, in addition to causing a temporary world-wide lowering of sea-level may have resulted in a general depression of the areas affected, a depression from which these areas have as yet only partially recovered. It would therefore be quite reasonable to expect certain areas to show evidence of this depression as well as the more obvious evidence of a later elevation.

b. Enormous accumulation of Pleistocene ice about the Poles might conceivably have resulted in such depression of the Polar regions as would cause actual elevation of certain latitudes—a distortion from which the affected areas have been recovering by a general downward movement of land-level.

Whatever form such regional movements, if any, may have taken in adjustment of the earth's crust to loading and unloading of the Polar regions, it seems necessary to suppose some such movement in order to account for the suite of terraces recorded in this paper. Only the lowest members of the series of terraces can possibly be explained by abstraction of sea water to form the existing Polar caps, and any terraced coasts which may have been exposed during the periods of maximum Pleistocene glaciation should now be submerged, if eustatic fluctuations of sea-level were the only effect of successive making and melting of Polar ice.]

F. THE USE OF MARINE TERRACES IN DEFINITION OF THE LIMITS OF THE NEW ZEALAND PLEISTOCENE.

Not the least interesting aspect of the correlation of terrace-development in New Zealand with that of Europe and South America is consideration of the evidence which may be afforded regarding the age of our younger sedimentary rocks. Our geological literature contains no very definite statement as to the limits of the Pleistocene formation or of the age of the Kaikoura orogeny which has had such a profound effect on the present physiography of the country. The most comprehensive modern survey of the local Tertiary stratigraphy is that of Thomson (1916, pp. 28-40; 1917, pp. 397-413; 1919, pp. 289-349; 1920, pp. 322-415). We are here concerned only, however, with the beds assigned by him to the post-Notocene—i.e., his Notopleistocene. He says (1917, p. 411), "As we have no evidence that the highest Notocene stage, the Castlecliffian, corresponds exactly to the youngest Pliocene rocks of the Old World, it is undesirable to use such a name as 'Quaternary' for the superficial rocks such as raised beach deposits, alluvial gravels and loess, of which all we know is that they are post-Castlecliffian, or even only that they are subsequent to the main Kaikoura deformation affecting the area in which they occur. It is still more undesirable to attempt to distinguish between Pleistocene and Recent deposits in New Zealand, where the fossil mammalia on which these distinctions have been based are not found."

He says further (1920, p. 412), "The Greta transgression was brought to an end by earth movements which caused tilting of the marine Notocene rocks in North Canterbury, and during the subsequent erosion the terrestial Kowhai beds were deposited. Finally came the major block faulting of the Kaikoura orogenic movements, by which all the Notocene beds were warped or tilted and the Southern Alps and Kaikoura mountains came into existence as high ranges. The subsequent history comes into the Notopleistocene. . . ."

Speight (1919, p. 281) says, "Therefore all that can be definitely stated is that the Kowai series overlies undoubted upper Pliocene beds and must be of a later age, and is most probably Pliestocene. This must be earlier than the gravels forming the Canterbury Plains, for these have suffered no deformation by folding movements, whereas the gravels of the Kowai series are at times folded somewhat acutely. They would therefore antedate the last period of glaciation to which the region had been subjected."

Marshall (1912, pp. 31-2; pp. 47-50) includes in the Pleistocene raised beaches up to 1,500 ft. (Preservation Inlet), the glacial moraines, peat swamps with moa bones, and gravel deposits up to 1,000 ft. high (Moutere Hills). He states, too (p.50), "The early Pleistocene was a period of great elevation and it is at once suggested that this too was the period of ice advance."

Park (1910, pp. 182-250) includes in the Pleistocene the major glacial deposits of New Zealand and mentions raised beaches up to 500 ft. He also (1911, pp. 520-4) includes gravel-deposits in Marlborough which appear, however, to be of much greater age, and not necessarily of glacial origin.

Henderson (1924, p. 580) says, "The land was at one time 1,000 ft. or more higher than it now is, but later was depressed till the old strand line was submerged to 1,000 ft. or more below its present level. The deposits formed prior to and during this depression are here considered of early Pleistocene, and those of the succeeding elevation of younger Pleiostocene age. . . . The deposits of the last mentioned (120 ft.) depression and subsequent elevation form the bulk of the Recent deposits of New Zealand." That is, Henderson regards the whole series of terraces from 120 ft. up to 1,000 ft. as younger Pleistocene, post-dating the glacial deposits.

Benson's summary (1921) of the recent advances in New Zealand geology indicates that little agreement exists as to the limits of the Pleistocene, and as to the age of the main Kaikoura orogeny (pp. 63-73). His suggestion (p. 66) that the Great Marlborough Conglomerate might possibly be correlated with the Kowai gravels described by Speight will be discussed in a subsequent paper.

From the foregoing summary of modern authoritative opinion on our later Tertiary and Quaternary geology it is seen that there is little agreement as to definition of the limits of the Pleistocene, and no satisfactory means of determining exactly what portion of the post-Tertiary deposits are to be regarded as Recent.

In the Old World, however, remarkable advances in the study of Quaternary geology have been made within the last decade. The present position is stated in the concise summary of Osborn and Reeds (1922, pp. 470-2, and Fig. 13). One of the most notable features of this advance in European geology is the correlation of marine platforms with the time divisions of the Quaternary. It has been shown above that the correspondence in the number of stages of the emergence of this part of the New Zealand coast and that of southern Europe is exact, and the accordance in level of the terraces quite remarkably close. It is most probable, therefore, that they must be more or less contemporaneous in both hemispheres, and if the validity of the use of marine terraces in time-division in Europe be sustained, then it may reasonably be applied in New Zealand. It must be remembered, however, that it is only this correspondence in sequence and level of terraces found on a comparatively small section of coast-line, which the writer has himself examined with considerable care, with those recorded by de Lamothe over a considerably greater area in Europe that is established in this paper. The validity of Depéret's (1918-1921) methods of broader classification and correlation of glacial and marine features cannot be discussed with reference to any material available in this area.

On the assumption, therefore, that the limits of the Pleistocene period in Europe are to be defined by the marine terraces ranging from the Sicilian Stage (90-100 metres) to the Monastirian Stage (18-20 metres), and that there is every probability that the similar terraces at corresponding levels in New Zealand are coincident in time, we would be provided with a more exact means of fixing the limits of the local Pleistocene.

It has been pointed out above (Part 1) that gravels which may be correlated with the Kowai gravels of Speight and which have hitherto been assigned to the Pleistocene have emerged in marine terraces up to 525 ft. On our present assumption as to the limits of the Pleistocene all these would then be regarded as Pliocene, and as they seem, too, to post-date the main Kaikoura orogeny, this deformational process would be of somewhat greater antiquity than hitherto supposed. In the present state of our knowledge of the glacial period in New Zealand, any attempt at correlation with marine terraces is impossible. New Zealand geologists are agreed as to the post-Tertiary age of our major glaciation, and Depéret includes practically the whole of the European glaciation within the Pleistocene, associating the Glaciation 1 (Scanian) with his terrace of 100 metres.

If, therefore, it can be established that the 350 ft. terrace is in New Zealand a measure of the lower limit of the Pleistocene, and established that the Kowai gravels (pre-glacial) are to be assigned to the Pliocene, then some advance is made towards a more definite knowledge of the age of our later Tertiary rocks.

Since the completion of this discussion of the division of Pleistocene time in New Zealand the writer has read Morgan's paper (1926, pp. 273-282) on the same subject. Morgan (p. 277) appears to have foreseen the possibility of some attempt at correlation of the Pliestocene in the Southern and Northern Hemispheres being "based on a study of the ancient strand lines." He summarizes clearly the present state of our knowledge of Pleistocene glaciation as it affected New Zealand, but there is nothing in the paper incompatible with the suggestions for precise division put forward by the present writer. Our knowledge of the glacial periods, locally, is still so far from complete as to render any attempt at their correlation with shift of sea-level quite impossible. The validity of the present writer's suggestions must depend on the validity of Depéret's correlations in Europe, and on the validity of regarding the marine terraces of both hemispheres as contemporaneous.

G. THE EUSTATIC HYPOTHESIS.

After collection of all the data with reference to marine terraces available in our New Zealand literature Henderson (1924, p. 591) states, "The above facts support the suggestion that New Zealand has moved in respect to sea-level during later Pleistocene and Recent times as a whole. Any differential movements between adjacent earth blocks that may have taken place during these periods must have been small, if compared to the plateau forming movements by which New Zealand has been uplifted as a unit."

With reference to the "Post Kaikoura Movements," Cotton (1916B, pp. 318-19) says, "It is important to note, however, that these latest movements generally have the effect, as far as any particular district is concerned, of "regional" as distinguished from differential movements—of epeirogenic as distinguished from orogenic. In a broad sense, however, these movements really are differential, for the New Zealand region has not moved as a whole. Units of much larger size than the blocks associated with the Kaikoura movements have moved independently. . . . It would seem that, though the Kaikoura movements may possibly be not quite extinct, they have very generally been succeeded, after a period of rest, by movements of the mysterious purely vertical kind which appear to have no connection with compression."

Many modern geologists believe that movements such as these are world-wide and are eustatic—the primary cause of marine transgression being the actual elevation of sea-level—and this view is supported by the great weight of the authority of Suess (1906). A belief in the eustatic hypothesis is also the basis of Depéret's correlations of marine terraces with alluvial and glacial features in Europe (1918-1921). The extent to which these views may be tested with reference to the coast-line surveyed by the present writer is limited, but the revelant facts which have come under his notice may be summarized thus:—

a. The sequence and heights of the terraces ranging from sea-level to 800 ft. or so may be regarded as being continuous from the White Bluffs to the Waipara River. There is sufficient evidence that the emergence affected Banks Peninsula to approximately the same extent.

b. The inner edges of the terraces, when traced over several miles (Motunau Plain), are not regular in height. Uneven elevation attributable in some measure at least to warping may amount to as much as 50-100 ft.

c. In some cases the outer (coastal) margin of the terraces may be as much as 150-200 ft. higher than the inland portion of the surface. The effect is a regular concavity due to warping (Blyth River).

d. The strata forming the surface-cover of the fragments of marine terraces may have a pronounced tilt away from the shore. In one case at least (south bank of the Waiau-ua River) they show considerable disturbance.

e. The most recent movement in the neighbourhood of Cook Strait is known to have been differential, and to have been accompanied by severe earthquake. In Cloudy Bay there seems to be a sharp line of division between a coast showing evidence suggesting recent uplift and one which is known definitely to have subsided in 1855. This, however, may be a localized movement resulting from local crustal instability and not affecting materially the question of a more general emergence of a recent coastal plain. As to whether the Marlborough Sounds area is a "downthrown block" in the sense that it has not participated to any extent in the general emergence, the writer has no knowledge. Hutton (1900, p. 177) remarks that an elevation of 500 ft. would restore the land-connection between the North and the South Island. Banks Peninsula shows a similar drowned topography, and while there is evidence that it was once much higher than now, it has more recently been submerged to a depth much below its present level.

The writer inclines to the belief of Henderson (*loc. cit.*) that any differential movements between adjacent earth-blocks are small as compared with the widespread emergence. It would seem to be a matter of considerable importance to distinguish between the great block-displacements belonging to the older mountain-building movements (Kaikoura), and any feebler continuation of these into a more recent period of general emergence of the land. The application of the eustatic hypothesis in explanation of shift of sea-level amounting to, say, 300 ft. to 500 ft. has its obvious limitations. Also the correlation of oscillations of sea-level with advance and retreat of glacier-ice has never been attempted in New Zealand, though the idea that the initiation of the glaciation was associated with higher land than now has found frequent expression in our literature. The general conception seems to have been that altitude was a controlling factor (Hutton, 1900, pp. 173-8; Marshall, 1912, p. 50), and that the land-level sank under the load of the ice, this being a factor in its retreat. That an isostatic response to unloading on the melting of the ice has been a contributing cause of subsequent elevation of the land has only, so far as the writer is aware, been mentioned by Speight (1926C, p. 56) and it seems quite possible that this may offer an adequate explanation of the entrenchment of some of our rivers in the glaciated floors of their valleys.

The present writer cannot imagine that any simple eustatic hypothesis is adequate to explain a series of terraces ranging between sea-level and 1,000 ft., even though the series be continuous over some hundreds of miles of coast-line. If, however, this complete series be shown to be of world-wide distribution, then some eustatic explanation must be sought; but if it is found that it is restricted to certain latitudes subjected to Pleistocene glaciation, then some measure of explanation may be found in isostatic adjustment to advance and retreat of ice-sheet (combined with the obvious effects of ice accumulation on the level of the sea itself), or in some regional deformation of the earth, the extent of which shows a more or less regular variation with latitude. It would appear that little advance towards solution of the problems presented may now be made, until the zealous exponent of the eustatic hypothesis will admit the capacity of diastrophism as at least a contributing factor.

With regard to the lowest (Recent) platform there is more definite evidence available locally. Daly, the author of the most comprehensive modern exposition of the eustatic theory (1915, pp. 158-251) discusses also the significance of this Recent platform in many parts of the world (1920, pp. 246-61). W. B. Bright, however, points out (1920, pp. 382-4) that the lowest platform of the British Isles, elevated in late Neolithic time, has suffered considerable deformation due to warping. Such irregularity of uplift seems to be characteristic of the platform on the north-east coast of the South Island, there being considerable areas from which it is entirely absent and in which the shore-line is receding rapidly. The rocks exposed to wave-attack, however, show such a variation in hardness that caution is necessary in interpretation of the discontinuity of the platforms, but nevertheless there is sufficient evidence to show that while some parts of the coast have emerged, closely adjacent areas have experienced slight depression. The matter is rendered more complex by the difficulty of determining the extent to which the recent strand-plains of this coast have arisen from progradation. Cotton (1914A), discusses progradation as the major cause of the strand-plain which extends for some 40 miles north of the Clarence River, though there can be little doubt that this area experienced some uplift in harmony with the movement which exposed the rock-platforms and raised the floors of the caves in Hålfmoon Bay a little to the south. While uplift in the latter locality may be conservatively estimated at 10-15 ft. above high-water mark, it is according to Cotton, only 6-8 ft. above mean sea-level at the mouth of the Flaxbourne River. With regard to many parts of the coast, however, the present writer has exercised caution in inferring any appreciable uplift at all, where the features of the strand may be explained as arising from other causes.

The wide plain near Amberley probably owes its existence to uplift, the effect of which has been accentuated by progradation, whereas the neighbouring Motunau coast shows definite evidence of slight subsidence, with rapid recession of the shore-line. Taken by itself this Recent discontinuous strand-plain seems to lend no support to the eustatic theory, but its occurrence in many localities in both islands of New Zealand is a very remarkable feature suggesting more or less uniform withdrawal of the sea. The writer would expect, however, that uneven elevation due to warping is a fairly general characteristic of it.

H. RELATION OF THE EMERGENCE TO THE KAIKOURA OROGENY.

Cotton (1913B, 1914A, 1914B) elaborates the views of McKay (1886, 1890A, 1890B, 1892) regarding the orogoney of Eastern Marlborough, views which have received the support of Thomson (1917, 1919), but which have been challenged by Park (1921). These views have been accepted by Speight and have been applied by him in explanation of the major physiographical features of North Canterbury (1915, 1926A). The question has been summarized by Benson (1921), who assigns the orogeny to the Pleistocene.

The writer has seen nothing in the course of his field-work in this area to lead to any material disagreement with the opinion of Thomson (1919, p. 295) as to the general sequence of the later Tertiary and post-Tertiary movements. These may be summarized briefly as follows: A sea-advance was accompanied by deposition of the Awatere beds (chiefly sandy marls), and this was followed by a slight general elevation. Then came the main Kaikoura orogenic movements by which the parallel chains of the Kaikouras were made, and this was succeeded by a lesser regional uplift (in which a suite of terraces emerged from the sea).

These terraces, however, do not appear to have arisen simply as the result of further upward movement in renewal of the Kaikoura orogeny, and there may be no direct causal connection between them. While the heights of the terraces are more or less uniform over a considerable length of coast-line, the effects of the major orogeny may also be more or less uniform throughout the area, for it has not yet been shown that the extent of the block-faulting diminishes to the southward. Cotton's statements regarding the origin of the Kaikoura Mountains require that vertical displacement due to faulting should amount to 10,000 ft. or more. If similar features in North Canterbury are to be explained in like manner, the amount of displacement cannot be very much less than this. It is to be inferred that the maximum elevation of the land was attained at the culmination of the Kaikoura orogenic movements, but these appear to have been succeeded by a long period of erosion and subsidence. The lower members, at least, of the suite of marine terraces result from re-emergence. According to Henderson (1924) there has been oscillation of sea-level, and it may be suggested here that the alternation of layers of vegetable material, and marine and terrestial gravels, sands and silts, revealed by deep-well boring near Christchurch (Speight, 1911A, plates 9-14) may result from this.

As has been noted above, Cotton (1916B) supposed the post-Kaikoura movements to be "of the mysterious purely vertical kind which appear to have no connexion with compression." He states further (p. 319), "There is evidence of a long period of rest—during which a cycle of erosion reached an advanced stage—intervening between the two sets of movements." It would seem, therefore, that our coastal terraces have no simple connection with renewal of movement in the field of the Kaikoura orogeny, and that their close correlation in sequence and height with similar coastal features in such widely separated parts of the world as Southern Europe and South America strengthens this conclusion.

I. CONCLUSION.

The discussion of some of the questions raised in Part 2 of this paper is based on certain hypotheses which may not be true. With regard to the continuity and approximate uniformity of the elevation of the north-east coast, the writer considers there can be little doubt. The remarkable correlation of the sequence and heights of the terraces in almost identical latitudes both in Europe and South America cannot very well be looked upon as a mere coincidence, and in this paper it is accepted as a simple fact. In the discussion of our later Tertiary and post Tertiary stratigraphy, however, the writer has merely set out the situation which would arise from acceptance of the contemporaneity of marine terraces in Europe and New Zealand, and the extension of Depéret's use of marine terraces as criteria for definition and division of the European Pleistocene to New Zealand. Whether they are contemporaneous and whether Depéret's wider correlations in Europe are based on sound geology must be left to future investigation. It has been pointed out that the usual criteria for such division do not exist in New Zealand, and our ideas as to definition of Pleistocene time are not very clear.

With regard to the review of Hutton's opinions as to the origin of the Canterbury Plains, this is merely an attempt to reconcile the idea that they must have emerged in harmony with the rest of the coast (which the writer finds it necessary to accept), with the fact that the existing surface features of the plains denote an alluvial origin. Since the writer has not examined the terraces of the major Canterbury rivers, no comment is made regarding the significance of these.

LIST OF REFERENCES.

The following is a complete list of works referred to in the text:—

BARTRUM, J. A., 1916. High Water Rock Platforms: A Phase of Shore-line Erosion. *Trans. N.Z. Inst.*, vol. 48, pp. 132-134.

BENSON, W. N., 1921. Recent Advances in New Zealand Geology. *Rept. 15th Ann. Meeting, A.A.A.S.*, Melbourne, Jan., 1921.

BUCHANAN, J., 1868. Kaikoura District. Abstract Rept. on the Progress of the Geol. Surv. during 1866-67. *Rept. Geol. Expl.*, No. 4, pp. 34-41.

BUICK, T. LINDSAY, 1900. *Old Marlborough*, ref. p. 332.

COTTON, C. A., 1913A. The Tuamarina Valley: A Note on the Quaternary History of the Marlborough Sounds District. *Trans. N.Z. Inst.*, vol. 45, pp. 316-322.

—— 1913B. The Physiography of the Middle Clarence Valley New Zealand. *Geol. Journ.*, vol. 42, pp. 225-245.

—— 1914A. A Preliminary Note on the Uplifted East Coast of Marlborough. *Trans. N.Z. Inst.*, vol. 46, pp. 286-294.

—— 1914B. The Relations of the Great Marlborough Conglomerate to the Underlying Formation in the Middle Clarence Valley, New Zealand. *Journ. Geol.*, vol. 22, pp. 346-363.

—— 1916A. Fault Coasts in New Zealand. *Geog. Review*, vol. 1, No. 1, pp. 20-47.

—— 1916B. The Structure and Later Geological History of New Zealand. *Geol. Mag.*, Dec. 6, vol. 111, pp. 243-249; 314-320.

—— 1918. River Terraces in New Zealand. *N.Z. Journ. Sci. and Tech.*, vol. 1, pp. 145-152.

COTTON, C. A., 1922. *The Geomorphology of New Zealand.* (Part 1), 1922.

DALY, R. A., 1915. The Glacial Control Theory of Coral Reefs. *Proc. Amer. Acad. of Arts and Science*, vol. 51, No. 4, pp. 158-251.

—— 1920. A Recent World-wide Sinking of Ocean-level. *Geol. Mag.*, vol. 57, pp. 246-261.

DARWIN, CHARLES. Geological Observations on South America.

DEPÉRET CHARLES, 1918-1920. Essai de coordination chronologique generale des temps Quaternaires. *Compt. Rend. Acad. Sci.*, Paris, 1918. Tome 166, pp. 480-6; 636-41; 884-8; Tome 167, pp. 418-22; pp. 979-84; 1919, Tome 168, pp. 868-73; 1920, Tome 170, pp. 159-63; Tome 171, pp. 212-8.

—— 1921. La Classification du Quaternaire et sa correlation avec les Niveaux Prehistoriques. *Compt. Rend. Geol. Soc. de France*, No. 9, pp. 125-127.

HAAST, J. VON, 1864. *Report on the Formation of the Canterbury Plains.* Canterbury Provincial Report, 1864, pp. 1-63.

—— 1871. On the Geology of the Amuri District, in the Provinces of Nelson and Marlborough. *Rep. Geol. Expl. during* 1870-1, pp. 25-46.

—— 1897. *Geology of Canterbury and Westland.*

HENDERSON, J., 1918. Notes on the Geology of the Cheviot District. *N.Z. Journ. Sci. and Tech.*, vol. 1, No. 3, pp. 171-174.

—— 1922. The Chertsey Oil-bore. *Ann. Rept. N.Z. Geol. Surv.*, No. 16C-2c.

—— 1924 The Post Tertiary History of New Zealand. *Trans. N.Z. Inst.*, vol. 55, pp. 580-599.

HUTTON, F. W., 1877. Report on the Geology of the North East Portion of the South Island of New Zealand, from Cook Strait to the Rakaia. *Rep. Geol. Expl. during* 1873-74, No. 8, pp. 27-58.

—— 1884. On the Lower Gorge of the Waimakariri. *Trans. N.Z. Inst.*, vol. 16, pp. 449-454.

—— 1900. The Geological History of New Zealand. *Trans. N.Z. Inst.*, vol. 32, pp. 159-183.

—— 1905. The Formation of the Canterbury Plains. *Trans. N.Z. Inst.*, vol. 37, pp. 465-472.

JOBBERNS, G., 1926. Raised Beaches in the Teviotdale District, North Canterbury. *Trans. N.Z. Inst.*, vol. 56, pp. 225-226.

—— 1927. The Canterbury Plains, Their Origin and Structure. *Natural History of Canterbury*, 1927, pp. 88-96.

KRIGE, A. V., 1927. An Examination of the Tertiary and Quaternary Changes of Sea-level in South Africa. *Ann. Univ. Stellenbosch*, vol. 5, Section A, No. 1, p. 81.

LYELL, C., 1868. *Principles of Geology*, 10th Ed., 1868, ref. p. 87.

MARSHALL, P., 1912. New Zealand and Adjacent Islands (in Steinmann's *Handbuch der Regionalen Geologie*).

McKAY, A., 1877. Report on Cape Campbell District. *Rep. Geol. Expl. during* 1874-76, No. 9, 1877, pp. 185-191.

—— 1881. On the Motunau District, Ashley County. *Rep. Geol. Expl. during* 1879-80, pp. 108-118.

—— 1883. On a Deposit of Moa Bones near Motunau, North Canterbury. *Rep. Geol. Expl. during* 1882, pp. 74-79.

—— 1886. On the Geology of the Eastern Part of Marlborough Provincial District. *Rep. Geol. Expl. during* 1885, pp. 27-136.

—— 1887. On the Grey-marls and Weka Pass Stone in Kaikoura Peninsula and at Amuri Bluff. *Rep. Geol. Expl. during* 1886-87, pp. 74-78.

—— 1890A. On the Geology of Marlborough and the Amuri County of Nelson. *Rep. Geol. Expl. during* 1888-89, pp. 85-185.

—— 1890B. On the Earthquakes of September 1888, in the Amuri and Marlborough Districts of the South Island. *Rep. Geol. Expl.*, No. 20, pp. 1-16.

—— 1892. On the Geology of Marlborough and South East Nelson (Part 2). *Rep. Geol. Expl. during* 1890-91, pp. 1-28.

MORGAN, P. G., 1916A. Notes on a Visit to Marlborough and North Canterbury, with especial Reference to Unconformities post-dating the Amuri Limestone. *10th Ann. Rept. N.Z. Geol. Surv.*, No. 10, C.-2b., pp. 17-29.

MORGAN, P. G., 1916B. Soft Limestone Deposits of Cape Campbell, Ward, and Waikari Districts. *10th Ann. Rept. N.Z. Geol. Surv.*, No. 10, C.-2b, pp. 15-17.

—— 1919. The Limestone and Phosphate Resources of New Zealand, Part 1—Limestone. *Bull. Geol. Surv. N.Z.*, No. 22 (New Series), pp. 1-316.

—— 1926. The Definition, Classification, and Nomenclature of the Quaternary Period, with Special Reference to New Zealand. *N.Z. Journ. Sci. and Tech.*, vol. 8, No. 5, pp. 273-282.

OSBORN, H. F. and REEDS, C. R., 1922. Old and New Standards of Pleistocene Division in Relation to the Prehistory of Man in Europe. *Bull. Geol. Soc. of America.*, vol. 33, pp. 411-490.

PARK, J., 1910. *The Geology of New Zealand.*

—— 1911. Some Notes on the Marlborough Coastal Moraines and Waiau Glacial Valley. *Trans. N.Z. Inst.*, vol. 43, pp. 520-4.

—— 1921. The Geological History of Eastern Marlborough. *Trans. N.Z. Inst.*, vol. 53, pp. 65-72.

SPEIGHT, R., 1908. Terrace Development of the Canterbury Rivers. *Trans. N.Z. Inst.*, vol. 40, pp. 16-43.

—— 1911A. A Preliminary Account of the Christchurch Artesian Area. *Trans. N. Z. Inst.*, vol. 43, pp. 420-436.

—— 1911B. The Post Glacial Climate of Canterbury. *Trans. N.Z. Inst.*, vol. 43, pp. 408-420.

—— 1912. A Preliminary Account of the Lower Waipara Gorge. *Trans. N.Z. Inst.*, vol. 44, pp. 221-233.

—— 1915. Intermontane Basins of Canterbury—Part 1. *Trans. N.Z. Inst.*, vol. 47, pp. 336-353.

—— 1917A. The Geology of Banks Peninsula. *Trans. N.Z. Inst.*, vol. 49, pp. 365-392.

—— 1917B. An Ancient Buried Forest Near Riccarton: Its Bearing on the Mode of Formation of the Canterbury Plains. *Trans. N.Z. Inst.*, vol. 49, pp. 361-364.

—— 1918. Structural and Glacial Features of the Hurunui Valley. *Trans. N.Z. Inst.*, vol. 50, pp. 93-105.

—— 1919. The Older Gravels of North Canterbury. *Trans. N.Z. Inst.*, vol. 51, pp. 269-281.

—— 1926A. Intermontane Basins of Canterbury—Part 2. *Trans. N.Z. Inst.*, vol. 56, pp. 355-360.

—— 1926B. Results given by Wells at Christchurch Pumping Station, Beckenham. *Trans. N.Z. Inst.*, vol. 56, pp. 363-368.

—— 1926C. Varved Glacial Silts from the Rakaia Valley. *Rec. Cant. Mus.* vol. 3, pt. 1, pp. 55-81.

SPEIGHT, R. and JOBBERNS, G., 1928. A Definite Break in the Tertiary Sequence in North Canterbury. *Trans. N.Z. Inst.*, vol. 59, pp. 213-231.

SPEIGHT, R., and WILD, L. J., 1918. The Stratigraphical Relationship of the Weka Pass Stone and the Amuri Limestone. *Trans. N.Z. Inst.*, vol. 50, pp. 65-93.

SUESS, E., 1906. *Das Antlitz der Erde*, Sollas's translation, vol. 2.

THOMSON, J. A., 1912. Field Work in East Marlborough and North Canterbury. *Sixth Ann. Rept. N.Z. Geol. Surv.*, C.-9, pp. 7-9.

—— 1916. On Stage Names Applicable to the Division of the Tertiary in New Zealand. *Trans. N.Z. Inst.*, vol. 48, pp. 28-40.

—— 1917. Diastrophic and Other Considerations in Classification and Correlation, and the Existence of Minor Diastrophic Districts in the Notocene. *Trans. N.Z. Inst.*, vol. 49, pp. 397-413.

—— 1919. The Geology of the Middle Clarance and Ure Valleys, East Marlborough, New Zealand. *Trans. N.Z. Inst.*, vol. 52, pp. 289-349.

—— 1920. The Notocene Geology of the Middle Waipara and Weka Pass District, North Canterbury, New Zealand. *Trans. N.Z. Inst.*, vol. 52, pp. 322-415.

WILD, L. J., 1915. Notes on the Soils of the Wairau Plain, Marlboraugh. *Trans. N.Z. Inst.*, vol. 47, pp. 413-16.

WRIGHT, W. B., 1920. Recent Sinking of Ocean Level. Letter to Editor, *Geol. Mag.*, vol. 57, pp. 382-4.