Further Notes on the Geology of the Trelissick or Castle Hill Basin.

No. II.

With Sketch Maps and Plates.

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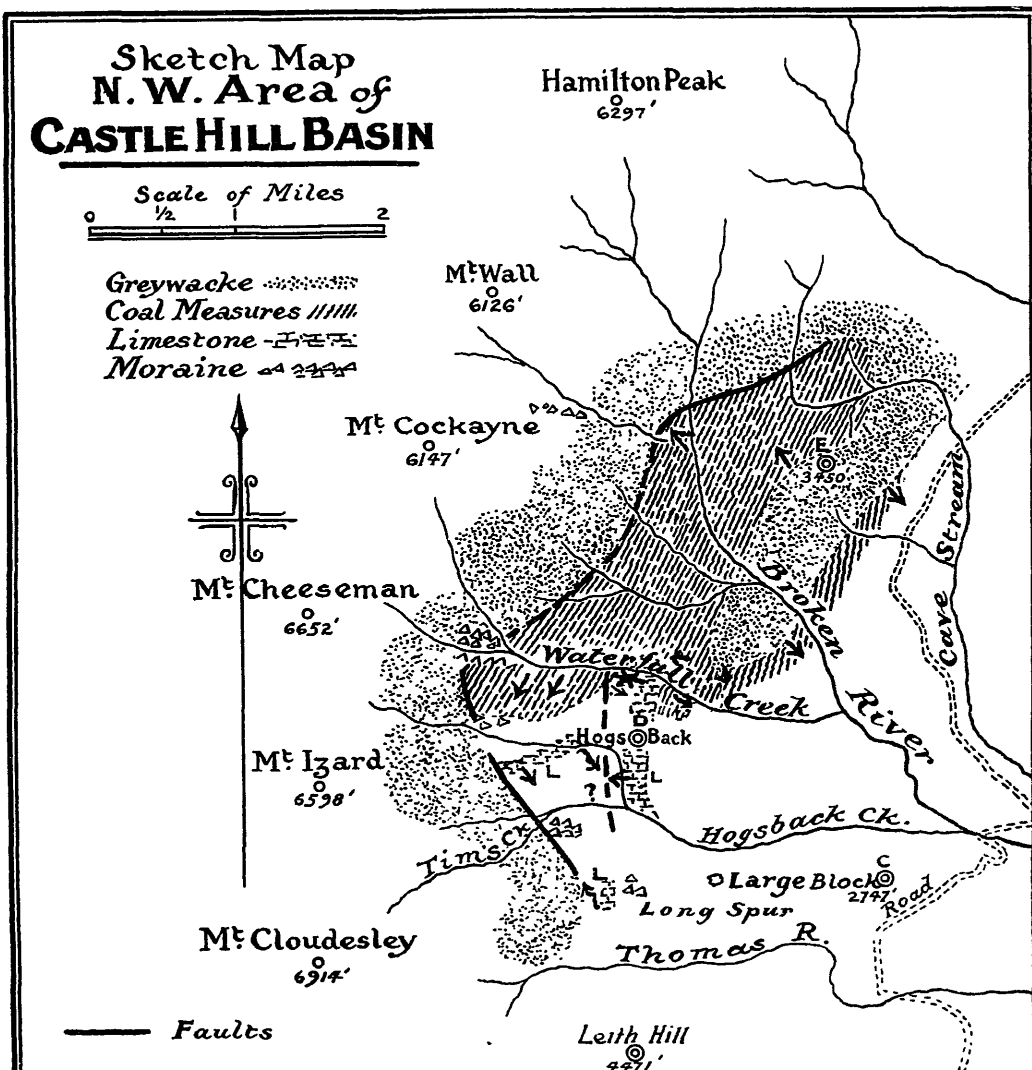
A.—Stratigraphy of the North-West Area of the Basin.

See Map A.

During recent visits to the Castle Hill district all available time has been devoted to an examination of the western side of the basin and particularly of the relation between the Notocene beds and the underlying pre-Tertiary greywackes and argillites. Since my previous accounts (1917 and 1919) a considerable area of bush has, unfortunately, been destroyed by fire, but this has enabled a clearer view of the structural features of portions of the margin of the basin to be obtained. The chief alteration in the account of the locality, as given formerly, is the record of the presence of an area covered with Notocene beds in the north-west corner of the basin, for north-west of the disjointed greywacke ridge which extends north-east from Waterfall Creek across the upper part of Broken River to near the road crossing of Cave Stream (formerly Murderers Creek) there lies an extension of the lowest beds of the series, i.e., coal measures, sands, clays, etc., not marked on the map (1917). This greywacke ridge forms part of the irregular floor of the basin and is the core of an anticline whose upfolding was posterior to the deposition of the covering beds, and is now exposed by the stripping away of what was once a continuous cover from the axial portion of the anticline. In the area just referred to from near Cave Stream almost to Waterfall Creek there is no remnant of limestones or other calcareous beds which characterise the middle portion of the Notocene series in the Trelissick area, only the lower members persisting, which are of Senonian age (Speight, 1917, p. 344). At the south-western end of the ridge near Waterfall Creek the middle Tertiary limestones occur, and their arrangement here and on the Hogsback clearly indicates that they experienced the same movements as the beds further north-east flanking the greywacke ridge.

The most typical section is that disclosed by an examination of Broken River above the first greywacke gorge, from three to four miles above the road crossing. Lying unconformably on the north-west side of this greywacke ridge are coal measures, consisting of sands, grey, greenish-grey with yellow efflorescence, and white, with



Map A.

streaks of shale, and one bed of poor lignite showing. They strike N. 15° E. and dip west at low angles. Their contact with the greywackes towards the west is a reversed fault, hading 80° in a direction N. 15° W. This is the only clear contact to be seen in any part of the area.

The beds extend N.E. over a low saddle lying N.W. of Trig. E into the neighbouring valley of Cave Stream, where their western margin is almost certainly a reversed fault, and from there on to the slopes of Mount Manson, judging from certain topographic features. South-west from Broken River the country is almost completely masked by terrace gravels and bush, but the coal measures are occasionally exposed in the banks of deeply incised streams. The beds flanking the greywacke axis are replaced in this direction by a definite anticline, and to the west lies a flanking syncline, the overlying limestones being involved as well as the coal measures, and show on the surface.

On the extreme western end of the ridge south of Waterfall Creek there are occasional exposures of coal measures including ferruginous concretionary sandstone, striking N.W.-S.E., and lying at right angles to the beds nearer the Hogsback, the junction between the two sets of beds being evidently a fault, with only a small throw, since coal measures lie in contact with coal measures on either side of it. The dip of the beds west of the fault is at low angles to the south-west. West of the upper part of the Hogsback Creek is a mass of limestone forming another hogsback, a quarter of a mile in length, which, owing to the destruction of bush, is more clearly seen than when I wrote my last paper (1919, p. 157). The strike is E.N.E. with a southerly dip at angles of 50° and over, so that it is almost parallel with the coal measures on the ridge to the north, and, judging from the stratigraphical relations elsewhere in the basin, they are both part of the same sequence. At the western end of the limestone ridge it abuts against the greywacke, and is tipped up at the junction, so that it presents a fault contact similar to that in Broken River.

The limestone in the bed of Hogsback Creek, at the end of this ridge, has evidently suffered some dislocation, and the strike varies between N. 55° E. and N. 75° E. where it crosses the stream. The dip is nearly vertical and varies in direction also. The bed probably continues to the north-east along the face of the hill and junctions with the limestone showing in the western limb of the syncline just south of Waterfall Creek.

In a stream rising between Mounts Cloudesley and Izard, known as Tim's Creek, which joins the Hogsback Creek near the southern end of the limestone ridge, occurrences of coal appear in several places. Their dip and strike are obscure, but near the junction with the Hogsback Creek they seem to conform with that of the limestone of the Hogsback itself. These beds are probably the stratigraphical equivalent of the upper coal measures as they appear in the Thomas and Broken Rivers; that is, they are posterior to the limestone. This is certainly the case in the lower part of the creek, but owing to the limited exposures and the absence of fossils this cannot be told for certain as regards the higher part.

The next appearance of the Notocene beds along the western margin of the basin is on the northern flank of Long Spur near its proximal end, where limestone shows through the covering of soil and debris for a few chains. In the part of the exposure furthest downhill the beds are much corrugated and have a general vertical dip and a strike N. 10° E., that is, in a line with the main mass of the Hogsback limestone. The ridge formed by the limestone is sinuous, but has a general strike of N. 20° E. and a westerly dip of 50°, sometimes 60°. The orientation of the upper part of the exposure near the crest of the ridge is in the direction of the outer flank of Leith Hill, which lies south of the Thomas. In one place there is a break across the bed which suggests a lateral movement of adjacent blocks following on a differential horizontal thrust.

This limestone mass probably forms the western wing of a syncline whose axis is sub-parallel to the upper part of Tim's Creek, the limestone west of the upper part of the Hogsback Creek forming the other wing, and, if so, the synclinal axis meets the line of the Hogsback ridge at an angle. This syncline is cut off on the west by a fault running along the base of the Craigieburn Range, and perhaps on the east by another running parallel with the Hogsback and west of the line of the creek as it follows along the base of the ridge. This may be a continuation of the undoubted fault which crosses the ridge south of Waterfall Creek. There is a possibility, however, that this last fault is of minor importance, and may be only a phase of the wide syncline of Tim's Creek, which pinches together when traced north and becomes the narrow syncline above the fall in Waterfall Creek. When this fold is traced south along the Hogsback, the eastern wing becomes increasingly tilted to the west and becomes slightly overturned at the southern end of the Hogsback ridge, and is no doubt faulted as well. This folding demands first of all a thrust from the N.N.W. or S.S.E. to account for the syncline whose axis runs along Tim's Creek, and as well a thrust from the W.N.W. or E.S.E. to account for the folding along the line of the Hogsback. The position may be explained by the syncline having an axis pitching S.W., with the south-easterly wing pushed over by a thrust from the E.S.E.

There seems to be a break between the end of the Hogsback and the limestone on Long Spur, and there must be a break east of this to account for the position of the "Pareora" beds in the lower part of the Hogsback Creek, south-east of the Hogsback ridge, and also those on the distal end of the Long Spur.

The whole locality is thus one where the beds are markedly disturbed, the frequent brecciation of the rock, and the rapidly varying dip at high angles, emphasising the point. The true relationship in some cases is therefore difficult to determine.

Further south along the slopes of Leith Hill the contact of the limestone beds with the greywackes appears to be a reversed fault, and this remark applies to the isolated mass of limestone at the mouth of the Whitewater gorge, which is cut off from its related beds to the east by a normal fault. In the Coleridge Creek section (1917, p. 334) the arrangement should be amended in the direction of representing beds beneath the limestone on the western side of the creek. As the result of a slip, the coal measures beneath the limestone are exposed.

It thus appears that the western boundary of the basin as a whole is marked in places by a reversed fault with steep hade, and it may reasonably be inferred that the contact where obscured is of the same nature. There is no evidence of marked overthrusting to indicate a considerable push from the north-west. In parts of the floor of the basin the fold directions are varied; for example, the line of the Thomas River shows a fold oriented almost E.–W., and this is practically the direction of the folding between Tim's Creek and Waterfall Creek; also the dip of beds to the east of Cave Stream, forming the mass of Flock Hill, swings round through a right angle. I can see no reason, therefore, for modifying my opinion that the folding can well be explained as the result of adjustments when the basin was formed as the result of the faulting down of a portion of the pre-Tertiary peneplain and its covering beds.

B.—Effect of Removal of Bush.

There are also one or two matters of purely physiographical interest that I should like to refer to. First of all, there is the effect of the removal of the bush covering from parts of the western side of the basin. When I examined this area originally, some forty years ago, the upper courses of streams such as the Thomas and Hogsback ran in confined channels obstructed by large boulders. Now these channels are filled up and the streams wander over somewhat wide shingle-covered beds owing to the increase in the supply of waste. Standing trees over a foot in diameter are partially buried and killed by the encroachment. Were this to continue for a substantial period it seems possible that the stream beds would be filled with waste to a degree comparable with what existed before the terraces were formed, and this supports the contention concerning the important effect of excessive waste on the history of terrace formation in this part of the country.

The deposition of detritus suggests consideration of what were the conditions of the floor of the basin during Pleistocene times and subsequently.

C.—Glaciation.

Both Hutton (1887, p. 395) and McKay (1881, p. 5) maintained that the basin had not experienced the direct effect of glaciation, but Haast (1879, p. 392) stated baldly that the Waimakariri and Rakaia Glaciers once joined by way of the pass where Lake Lyndon is now situated. In view of these conflicting opinions, the matter was reconsidered in order to arrive at a definite opinion if possible.

Near the source of Broken River the valleys are certainly headed by corries, and small valley glaciers came out on the floor of the basin in that locality. At the head of the main stream lies a U-shaped glacial trough and above it a corrie at the level of 5000 feet (Plate 52). Similar features occur in the valleys to the west of this.

On the south side of Tim's Creek, at a point where it leaves the greywacke slopes and enters the floor of the basin, there is an area covered with morainic dumps (Plate 53). As far as can be seen, these are composed of large angular blocks which can neither be slip nor a stream deposit. At the outlets of Hogsback and Waterfall Creeks from the greywacke range there are similar deposits with the form of ridges of large blocks converging downstream; that is, they are latero-terminal moraine, and in the latter creek there is true terminal moraine. These deposits do not belong to a recent phase of glaciation, judging from their surface features; they are rounded and covered with soil, and compare most closely with the outermost morainic deposits of the Rakaia Valley, and therefore belong in all probability to the stage of maximum glaciation, which dates from a time long antecedent to the moraines which have been little modified.

The northern side of Long Spur and the terrace at its base are marked in various places by nests of large angular blocks, but the most remarkable block lies on the terrace about three chains from the base of the spur. It is angular and partly embedded, but the visible portion measures 15ft. by 14ft. by 5ft. (Plate 54), composed of a type of greywacke not showing on the mountain slopes in its immediate vicinity, and it lies over half a mile from the base of the hills. Transport by glacier appears to be the only way in which it can have been carried and deposited in its present position.

These are the only definite evidence of the presence of ice in the basin, but there are other suggestive phenomena. First of all, judging from the forms of the hills near Craigieburn, a powerful stream of ice must have run past the north-western end of Broken Hill towards Broken River and Mount Torlesse. Faceted spurs and ice-shorn slopes indicate this clearly. There are also similar faceted spurs on the slopes of the Craigieburn Range just inside the basin. These may be attributed to faulting, though there is no clear evidence from the floor of the basin itself of recent faulting on this line. The main faulting must have been pre-glacial.

At the other end of the basin similar faceted spurs occur on the face of Mount Torlesse, and on both sides of the valley leading to Lake Lyndon, and probably in the upper valley of the Porter River in the direction of Coleridge Pass. These latter, as well as those near Lake Lyndon, may be fault-scarps, but the latter are more strongly suggestive of glaciation, since, if fault scarps, they would demand evidence of faulting on the same line in the vicinity of Porter River, and this does not occur. It must be remembered, too, in this connection that ice did actually cross the spurs of the Benmore Range to the south-east of Lake Lyndon at a height of over 3000 feet. Although this may more reasonably be attributed to a distributary stream from the Rakaia Valley, the deposit may have been caused by a glacier coming down from the north past Lake Lyndon, and to this glacier may be attributed the faceted spurs on the walls of the valley north of the lake, and perhaps also the moraine across the Acheron Valley below the lake. There is also the practical certainty that ice invaded the basin from the Rakaia Valley by way of the Coleridge Pass, since there is evidence of the presence of ice on the Rakaia side of the pass in its immediate vicinity at a much higher level.

Thus we have definite evidence that glaciers came down on to the floor of the basin from the Craigieburn Range on the west, while at the northern and southern ends there are phenomena which can be best explained by the presence of ice. If this is so, then it is likely that a considerable part of it, or perhaps even the whole of it, was covered by ice at the height of the glaciation. What, then, is the reason for the absence of traces from its floor? One can only suggest that the streams issuing from the retreating ice-front removed all traces of glacial deposit from the eastern and north-eastern portions. This is quite conceivable when one remembers the long reaches of the river valleys of Canterbury which show no deposits to be credited to ice action.

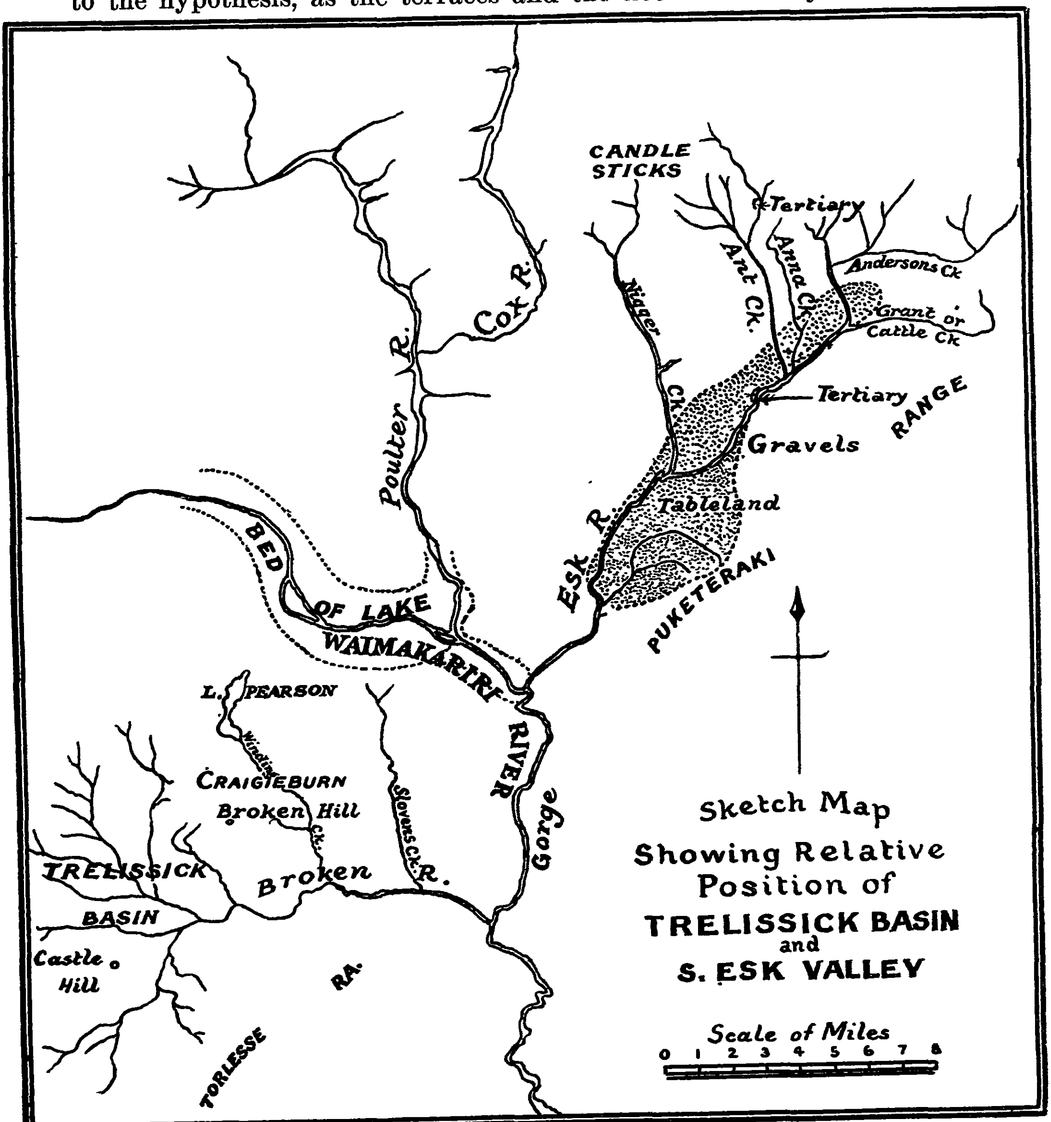
The general evidence indicates that a considerable amount of erosion of the Tertiary beds had taken place before the onset of the glaciation, and it no doubt continued when the ice was retreating from the basin and its vicinity, and after it had left the area. Some of the land forms on the floor of the basin date from pre-glacial times. It may be concluded that the Long Spur and also the terrace north of it had something of its present form during the ice advance, for the moraine at the mouth of Tim's Creek, as well as the large erratic lying on the top of the terrace some distance away, have been laid down on this terrace, so it was in existence in pre-glacial times. The large blocks on the flanks of the spur may likewise have belonged to a lateral moraine of this glacier, and have been shed from its side when the glacier covered the floor of the terrace.

D.—Was the Basin once a Lake?

See Map B.

McKay (1881, pp. 58–60) considered that the basin was at one time occupied by a lake, that debris from the neighbouring mountains poured into it, ultimately filling the lake and aggrading its floor, while an outlet was being lowered through the downward cutting of the stream to the east and north-east of the basin, the limestones being incised as the Broken River and Waimakariri further east lowered their beds. During this period of delayed erosion aggradation continued, and the channels of the streams were widened in the weaker beds above the limestones.

Although this sequence of events may be reasonable, I know of no direct evidence of the former presence of a lake in the Trelissick Basin. There are no stratified gravels or silts that I am aware of, and the floor is not level. This may not be an insuperable objection to the hypothesis, as the terraces and the floor itself may have been



Map B.

warped as the result of earth movements, or the basin may have been tilted as suggested by Hutton, although he puts his tilting much earlier. I can see no difficulty, however, in the basin having been a waste-filled plain, like the Hanmer, Maruia, or Upper Buller Plains, or the Mackenzie Country, while glaciers filled the neighbouring valleys. No doubt each of the streams issuing from the mountain tract to the west of the basin had its fan, and the coalescence of these formed the floor of the area, and thus its approximately—for it is only approximate—level surface can be explained, the departure from absolute horizontality being due to the varying conditions of the streams issuing from the Craigieburn Range or from the front of the ice to the north or perhaps to the south. These streams would differ in size and in the amount of waste material they carried, and thus their grade would vary, causing any unevenness in the main floor existing now.

The hypothesis of the former existence of a lake must be considered in the light of the fact that a lake did occupy the floor of the Waimakariri Valley in the reach downstream from the Cass to the mouth of the Esk. (See Map B.) Its former presence is evidenced by glacial silts and by level terraces marking its old shore line. Glacial silts, some of them varved, occur in the lower reaches of the Poulter, but I have seen none in the Esk. The traces of this lake indicate that it was at a higher level than the present floor of Slovens Creek, but this would not account for the existence of a lake in the Castle Hill basin. This lake, too, was ponded back behind a rock barrier just below the mouth of the Esk, now deeply incised by the main stream of the Waimakariri. The hollow above the barrier may have been structural in origin, but it was certainly modified by glacier action. If due to movements of the crust they must either have been pre-glacial or contemporaneous with the occupation of the upper part of the valley by the glacier, since glacial silts occur in it. It is not maintained that the present hollow was in existence then, but a hollow did exist for certain. The movement responsible for the formation of the barrier must have commenced, if, indeed, it had not concluded, before the end of the glacier advance.

There is, however, in the Esk Valley a great deposit of stratified gravels, best developed on what is called the Tableland, a flat area 3000 feet above sea-level, and lying three to four miles above the confluence of the Waimakariri and Esk (Plate 55 and map B). This was once covered with forest, but a fire has destroyed most of it, though a bush-covered extension of the plateau continues for two miles further up the Esk in the form of a high terrace. The beds of which the Tableland is composed lie flat, that is, parallel to its upper surface; they are mostly of gravel, but this is interstratified with beds of sandy clay and sand. They rest on greywacke, and the river has now cut its course through the gravels and incised the solid basement. It might be noted here that the destruction of bush was followed by marked erosion of the gravels on the edge of the plateau facing the Esk, and "badland" topography has become typically developed. (See Cotton's Geo-morphology of New Zealand, p. 191.)

These gravels occur on both sides of the stream, and extend north-east beyond the Tableland at a lower level across the lower courses of the Nigger and Ant Streams, past Anna Creek and Grant (Cattle) Creek nearly as far as Anderson's Creek. They reach north-west nearly a mile up the Ant and Anna, in the neighbourhood of which they form an extensive flat terrace lying at a height of from 2700 to 2800 feet. The drop to this terrace from the top of the Tableland is sudden, and there are no intermediate shelves. This is incised in turn, and there are numerous terrace remnants at various levels till the bed of the Esk is reached. The suddenness of the drop from the Tableland and the extent of the terrace just referred to are remarkable (Plate 55).

The gravel deposit is most extensive, and therefore indicates some special conditions favouring its accumulation. In general the bedding is flat, but along the northern boundary of the terrace the beds had been tilted prior to its formation. The strike is here W.N.W.–E.S.E. approx., and the dip southerly at angles of from 25° to 30°. The lowest beds exposed in the Ant consist of whitish and greenish-grey sands, sandy clays, and irregular gravels interstratified with sands. In the Anna, which lies parallel with the Ant and a short distance to the east, green-grey sands and chocolate coloured clays occur interstratified with subangular gravels, the largest pebbles of which reach 8 inches in diameter. These beds extend north-east to the main Esk between Cattle and Anderson's Creek on the slopes of the Puketeraki Range, and have the same strike and dip throughout. The inclination is due to subsequent deformation and not to fore-setting. There are also heavy deposits of gravel in the valley of the Poulter, above and below the junction of the Cox.

There is no precise evidence as to the age of the Esk gravels, but they may be tentatively assigned on lithological grounds to the Kowai Series of North Canterbury. Marine Tertiary beds do occur in the locality, but the relations of the gravels to them is obscure. Large fragments of rock containing fossils were found during a recent trip in a tributary of the Ant on the slopes of the Candlesticks at a height of approx. 3500 feet, and Dr Marwick has assigned these to the Mid-Tertiary, and almost certainly to the Awamoan. On the right bank of the Esk, about a mile below the Anna Hut, there is an exposure consisting of the following sequence:—

1. *Grey sands,* lying down at water level.
2. *Coal,* lignitic, 6 inches thick.
3. *Fireclay,* 6 to 12 inches.
4. *Streaky sandy shales and grey sands,* 15 feet.
5. *Yellowish-white sands,* with stains of iron oxide, the pebbles in the vicinity being covered with a white incrustation of iron sulphate or alum.

These beds strike N.E.–S.W. and dip N.W. at high angles. They are affected by a fault which runs in the same direction. The exposure is obscure owing to the height of the river and the cover of terrace gravels, but at the downstream side of the occurrence, which, after all, is only about 4 chains in length, there are irregular cemented gravels resting on greywacke in close proximity, but their

Glaciated Valley at the head of Broken River, with cirques at the head and cross-sections modified by screes coming in from the sides and from the rock-slopes above.

Face p. **312**

Morainic Dumps at mouth of Tim's Creek, showing in the middle. Cirques at head of Waterfall Creek on the slopes of Mounts Cockayne and Cheeseman in the background.

Perched Block, 15ft by 14ft by 5ft, on the terrace north of Long Spur, which shows on the left. The stick leaning against the rock is over 4ft in length. The morainic dumps of Plate B show to the left of the rock in the middle distance. Large blocks also occur along the fringe of bush, and on the slopes of Long Spur near the beech tree. Some of these are 10ft in length.

"Tableland" in the Esk Valley, composed of flat-lying gravel beds. This was once covered with forest, but it was almost entirely destroyed by fire, and then the "badland" erosion set in. Puketeraki Range at the back, and the level terrace of the "Ant" in the foreground. The view is looking south-west and down the Esk River.

precise relationship is obscure as well. I am told by Mr R. Turnbull, the lessee of the Mount White Station, that fossils have been found in close proximity to these beds, though I saw none on my various visits. Unless they are disturbed locally owing to faulting, their pronounced dip and the difference in strike from that of the gravels in the vicinity, though it must be admitted not the immediate vicinity, indicate that they underlie the gravels unconformably.

The flatness and even stratification of the gravels indicate that they were laid down in comparatively still water, and it is thus possible that a lake occupied the lower part of the course of the Esk. There is at present no rock barrier indicated that would pond back this water from the Waimakariri side to the height of the top of the Tableland, but there is a certainty that the ice at its maximum extension could furnish such a barrier, for there are clear evidences of ice at a height exceeding 3500 feet in the Craigieburn region of the Waimakariri basin, and this would be quite sufficient to furnish the required barrier if the ice extended on to the slopes of the Puketeraki Range below the junction of the Esk. There is little doubt that this was the case, and if the lower reach of the Esk were free from ice at the same time, there would be opportunity for the deposition of these gravels under the required conditions. A difficulty in accepting this explanation in its entirety is the determination of the precise date of these gravels. In order for it to be satisfactory, they must date from the time when the central Waimakariri was occupied by ice and the lower reach of the Esk free from it and occupied by water. The synchronism cannot be demonstrated. There is therefore no definite support from the valley of the Esk of the contention that the Trelissick Basin was once a lake, but the evidence is in support of the hypothesis that the barrier of greywacke to the east of the basin was in existence in pre-glacial times or at any rate before the ice had commenced its last retreat, and that it has been cut through subsequently.

It is noteworthy that the main coalesced drainage from the Waimakariri intermont follows along the base of two ranges, viz., the Puketeraki Range and the Mount Torlesse Range, and there is comparatively little drainage in the middle of the area, only two streams being worth mentioning, viz., Winding Creek and Slovens Creek, both of minor importance. This may reasonably be explained by supposing the main part of the basin to have been filled with ice, and the streams therefrom discharging along the margin of the main flow, just as the Murchison River discharges along the margin of the Tasman Glacier. The impinging of the ice against the slopes of Mount Torlesse would provide a temporary barrier against the cutting down of the river channels in the Trelissick area, and thus help in the formation of terraces. All the same, the dominating agencies in this area connected with the formation of terraces appear to be the retardation in the cutting down of weak beds by solid rock barriers, such as the limestone and greywacke to the east of the Trelissick Basin, and the latter downstream from the mouth of the Esk, as well as the warping of the crust on an axis running N.E.–S.W. and practically cutting across the Waimakariri in the gorge of that river.

I am making no further reference to the terrace system of the basin, since I understand that Mr Jobberns has the matter in hand.

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