NOTE ON THE ORIGIN OF THE GREAT LAKE AND OTHER LAKES ON THE CENTRAL PLATEAU.

By

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Plates VII.-XX.

1. INTRODUCTORY.

The Central Plateau of Tasmania is a pivotal feature of Tasmanian physiography and industrial enterprise, but has been rather neglected by geologists. The topography of the plateau has been well known since the earliest days of the pastoral industry, and several general accounts are available (see, e.g., the references at the end of this paper). Much of the plateau is still difficult of access, although the roads to the fishing resorts and engineering works have made considerable sections far more accessible than was the case thirty years ago. A current, though erroneous, opinion, that the surface of the plateau is covered with uniform dolerite, is not glaciated, and carries little interesting vegetation, has been largely responsible for a seeming lack of interest.

I feel that it will be many years before I am in a position to offer a complete geological map of the plateau, in view of the number of years that have elapsed since I first commenced this task, but I also feel that I should present these notes to amplify the recorded descriptions of this most important region, and to correct some errors which have worked confusion in general statements of Tasmanian geology.

2. THE CENTRAL PLATEAU.

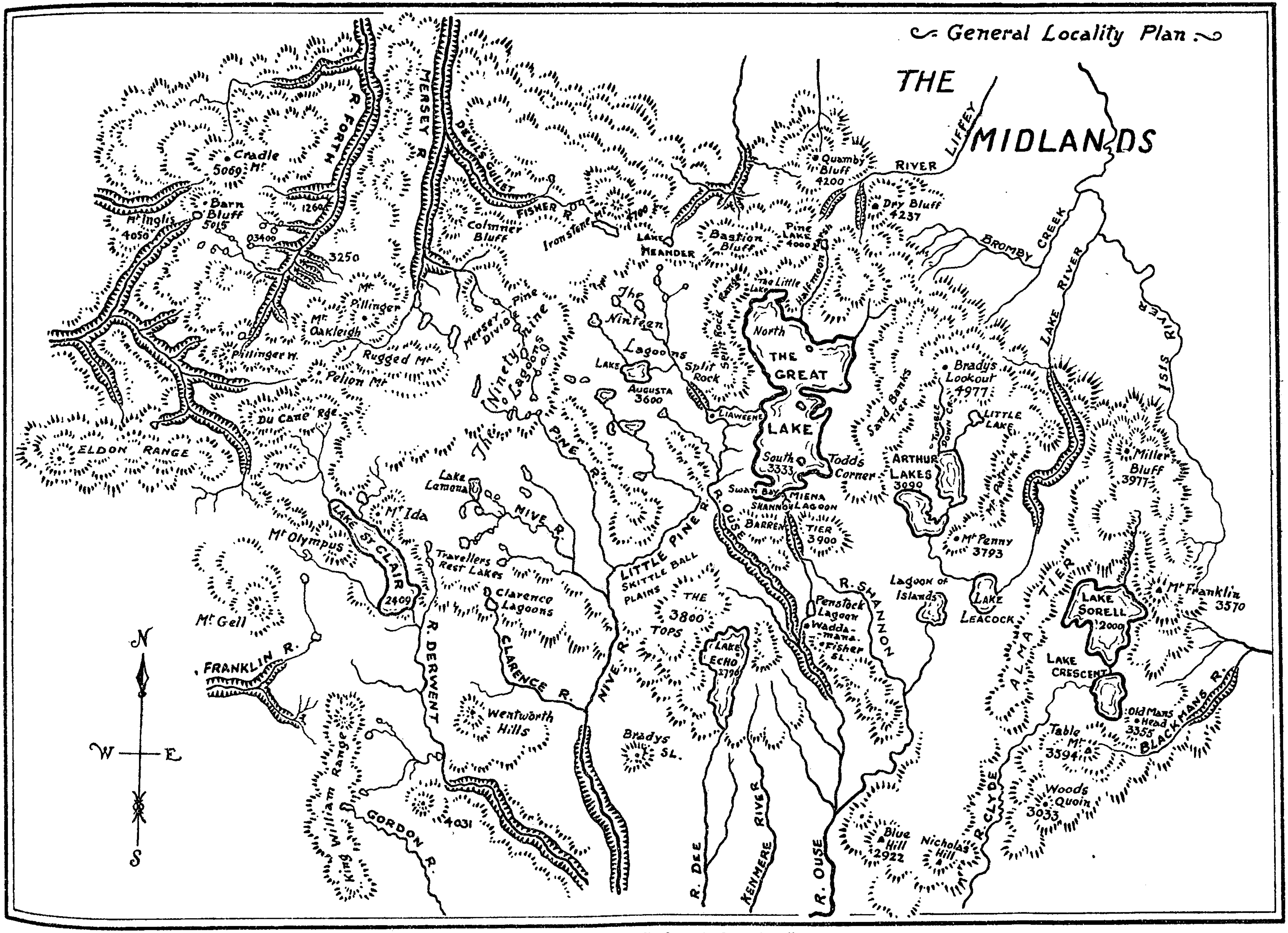
The area under discussion is an accepted geographical feature bounded by lines connecting Cradle Mountain, Dry Bluff, Miller Bluff, Table Mountain, and Mount Olympus, with the Eldon Range, Mount Gell, the King William Range, and Black Bluff as outliers, an area of some 2000 square miles, averaging 3000 feet in elevation, and with marked escarpments to the lower lands below. The best description is to be found in R. M. Johnston's "Geology of Tasmania" (Johnston, 1888), although the Denison Range should not be included. Further general description by me must be excluded for lack of space.

3. Previous Accounts and Opinions.

General descriptions such as those contained in Breton's account of a trip from Cressy to the Great Lake (Breton, 1846), and in Geoffrey Smith's account of his trip from Bothwell to the Great Lake and thence to Lake St. Clair (Smith, 1910), are interesting, but throw no direct light on the geology of the area. Accounts published in Strzelecki's and R. M. Johnston's geologies (Strzelecki, 1845; and Johnston, 1888) are to such an extent based on discarded theories as to be now only of historical interest. Colonel Legge's work (Legge, 1902, 1903, and 1904) is of vital importance to the geographer, and its detail must be of value for all time as a basis for any work on the Great Lake; but, again, it is not directly a geological account. These facts limit the previous accounts of the geology of the region to a very small scope.

Most of the western edge of the plateau has been very fully described and mapped—the Cradle Mountain-Barn Bluff district by Dr. Benson (Benson, 1916); the Pelion district, immediately to the south, by Mr. McIntosh Reid (Reid, 1919); and the Lake St. Clair district by Mr. Clemes (Clemes, 1924). This leaves only the Du Cane Ranges untouched in that section. A corner of the eastern edge, round Lake Sorell, has been mapped by Mr. Nye (Nye, 1921). As to the remainder of the plateau, the great area of upland moors, lakes, and tiers, there is no detailed geological account, and I regret that I can contribute so little to remedy this deficiency.

In 1893 the late Mr. R. M. Johnston said: "I have, from long observation, arrived at the conclusion that the larger lakes on the higher levels of the greenstone plateau—such as Lake St. Clair, Lake Sorell, Lake Echo, Lake Arthur, and Great Lake, together with innumerable lakelets and lagoons on the upper levels—have been mainly determined by the original irregularities of the surface, produced partly by the anastomoses of successive flows of greenstones during their eruption, and partly by the unequal contraction due to lack of homogenity of the cooling surfaces of the more massive horizontal flows of greenstone magma . . . . ."



General Locality Plan—Scale 1 inch to 8 miles.

(Johnston, 1893). Such view depended on the idea that the dolerite (greenstone, diabase) was eruptive. This theory has long since been discarded, but Mr. Johnston's explanation of the origin of the large lakes has not been revised. Mr. Johnston, in the same paper, discounted the suggestion that these lakes may be of glacial origin. Speaking only of Lakes Sorell and Crescent, Mr. Nye said, in 1921: "These two lakes occupy depressions in the diabase formed by the denudation of the Trias-Jura sediments which once covered this part of the plateau." And, again: "Not the slightest evidence of any Quaternary glaciation is to be found, and it is concluded that this part of Tasmania escaped the glaciation of the above period, so common in the western part of the State" (Nye, 1921). About the same time Mr. Loftus Hills, then Government Geologist, stated to me that, in the course of an investigation of the site of the Great Lake dam at Miena, he could not find any trace of morainal deposits at the outlet of the lake. Colonel Legge recognised the effect of present-day ice on the Great Lake, but did not comment on the possibility of a glacial origin. In passing, I desire to call attention to some remarks on the general geology of the plateau made by the late Mr. Tom Stephens in 1899 (Stephens, 1899), which remarks are fully borne out, as far as they go, by my observations. Reference should also be made to the fact that since 1912 the Journals of Parliament (Tasmania) contain an annual report of the Hydro-Electric Department, and of the hydrometric survey conducted by that department for some years, with plans, some sketch-maps, and photos. These provide a history and description of the engineering operations of the department and some account of the Great Lake-Ouse area. No direct geological information is contained in these reports.

4. Geology of the Plateau.

The Central Plateau consists of a base of Pre-Cambrian to lower Palæozoic rocks, covered unconformably by Permo-Carboniferous and Triassic sediments, deposited in a manner which clearly shows the existence of an undulating topography at the commencement of the deposition and a gradually sinking sea-floor. The older rocks appear from the vicinity of Quamby Bluff, westward and southward to the vicinity of Mount Arrowsmith, but are not exposed under the more recent series on the east and south of the plateau. The whole sedimentary series was penetrated by dolerite at the close of the sedimentary phase (probably middle Triassic), but the dolerite, as is usually the case, particularly invaded the upper coal measures and sandstone rocks of the Triassic period. I do not think that the dolerite can be regarded as one sill. Detailed mapping will probably show many irregular transgressive masses, with large horizontal sills intruding outwards in one or more directions. Many of the more spectacular escarpments, such as Table Mountain and Dry Bluff, represent the passage of fault-lines through such sills, and, to the westward, in the area in which lower-Palæozoic and pre-Cambrian rocks are now seen at an elevation of 2000-4000 feet, the sill extensions appear to have been more pronounced.

Dolerite, massive or as accumulations of talus, occupies the greater part of the surface of the plateau, but sedimentary rocks (Triassic sandstones and Permo-Carboniferous mudstone) appear on the boundary escarpment of the Western Tiers from an elevation of about 2800 feet downward, in most of the valleys draining the plateau and in many places on the plains of the higher elevations. Sedimentary and metamorphic rocks compose many of the prominences towards the north-west corner, even up to elevations of 4000 feet (see Plate XXXVI.: "Coal Resources of Tasmania"; and Reid, 1919, Plate IV.). Much of the surface of the plateau, particularly on its southern slopes, is covered with olivine basalt lava-flows assigned to Tertiary age, and, in places, these overlie and protect Tertiary river conglomerates.

The whole mass of the plateau is marked with faults, traversing all rock series. No information is yet to hand as to the age of this faulting, or as to its relationship with the general uplift of the plateau. Efforts to trace the fault-line usually end at a spot where, apparently, one dolerite mass is faulted against another, and information as to general trend lines and other important data which will be provided by accurate mapping must await the completion of this task. There is little doubt in my mind that many of the minor features of the plateau, such as escarpments, tiers, and river valleys, are largely controlled by fault-lines. There appears to be a general tilting of the plateau mass from the north-west downward towards the south-east, but this is probably the results of a complicated series of step faults rather than a bodily tilting of the whole mass. Evidence exists that the uplift occurred earlier in the north-western area than in the south-eastern, and that the move-

[A. N. *Lewis*, *Photo.*

I. *Lake Sorell* from Interlaken. Mollie York's Night Cap in background.

[A. N. *Lewis*, *Photo.*

II. *The Western Tiers*, looking south-east from edge of tiers, north of Arthur Lakes, across gorge of Lake River.
Miller Bluff in background. Mount Patrick in background to right.

To face page 18.]

ment progressed south-easterly in large separate segments, becoming less marked during the progress.

Of the later sedimentary series, the upper marine mudstones are common round the base of the Western Tiers, in the valleys of the Mersey, Forth, and Ouse, and elsewhere round the south and east of the plateau. Lower coal measures have been reported as occurring at Bashan, and lower marine limestones high in the gorge of the Meander. Probably other occurrences will be found when the Western Tiers are mapped. Ross sandstones occur under the dolerite in almost every exposure of the bottom of the sills, and also on top of that rock in many places. Felspathic sandstones and shales occur in a few localities.

The geology of the plateau corresponds remarkably to that of adjoining areas, e.g., the Midlands or Bothwell-Hamilton district. The higher ridges are composed of dolerite, and stand out as long, narrow, and usually flat-topped lines of hills. In between lie rolling plains, covered largely with sedimentary rocks and basaltic lava-flows, and broken by lesser hillocks, often of dolerite. No one, when looking over any of the plains of the upper levels of the plateau, can help being struck most forcibly with the remarkable resemblance of that landscape to the Midlands plain. All the evidence at present to hand points to the conclusion that the Central Plateau is geologically a continuation of the Midlands, and that both these regions have been subject to identical physiographic influences during the greater part of the cycle in which the plains have been developed.

The more I consider the development of such features of Tasmanian physiography as the Central Plateau and other similar elevated blocks, the stronger I adhere to the general view as to their origin, already expressed (Lewis, 1926 and 1927), namely, that we see a post-dolerite (probably late Tertiary) peneplaination or semi-peneplaination, followed by the uplift of the plateau blocks to the position in which we know them. It is difficult to imagine the Western Tiers as anything other than a remarkable fault scarp. The present drainage can hardly have been responsible for the topography of the upper levels of the plateau. The gorges of the Forth, Mersey, Meander, Liffey, and Lake Rivers flowing north, and those of the Ouse and Derwent flowing south, are very recent features; but the elevated plateau mass shows features of a cycle previous to that initiated by the uplift. The degree of post-glacial river erosion apparent in all these gorges is such as to preclude the possibility of the existence of the plateau features since the time of the dolerite intrusions. I regret that more attention has not been accorded to my explanation of Tasmanian physiography in the last six years, as, until this problem is settled, geographical work in general in this State must run the risk of being based on a fallacy.

The fuller examination which I have been able to give to the Central Plateau than has been possible to other workers, aided by experience gained elsewhere, enables me to say with certainty that the whole of the upper levels (above 2400 feet on the western side, 3000 feet on the eastern) were subject to ice-cap conditions during the Pleistocene ice age. This aspect will be more fully discussed later. The term "ice-cap" as used in this paper is to be taken as meaning an accumulation of ice on a mountain possessing a wide expanse of comparatively level surface. The features of the ice in this area show merely the characteristics of valley glaciers, with some modifications due to the plateau conditions, and the term is not used as indicating the features of a Continental ice-sheet.

5. Lake Sorell Area.

This district has been sufficiently described by Mr. Nye (Nye, 1921). The range forming the elevated edge of this plateau, and extending from Molly Yorke's Night Cap through Mount Franklin, and the Old Man's Head to Table Mountain, averages 3500 feet above sea-level, and was well above the snow line during the period of maximum intensity of the ice age. Ice appears to have moved from good névé collecting grounds in this high land. Glacially transported erratics are sparsely scattered over the flat and swampy course of the Mountain River, which enters the northern side of Lake Sorell (2800 feet). (This is just outside the area mapped by Mr. Nye.) Ice clearly moved southwards into the plain now occupied by the lake through one or more of these valleys. Suspicious, although vague, evidence exists of slight movements north-westward from Table Mountain towards Lake Crescent, and eastward from the Alma Pass tier towards Lake Sorell. Nowhere have I traced obvious morainal deposits except in the valley of the Mountain River, but it is quite possible the lakes now conceal the locality of the termination of the ice. Nevertheless, the area was subjected to Pleistocene glaciation to some extent.

P. and P. Roy. Soc. Tas., 1932. Plate IX.

[A. N. Lewis, Photo.

III. *North Arthur Lake.* Mount Patrick in background. Morainal deposits in foreground.

[A. N. Lewis, Photo.

IV. Rudimentary Cirque at head of the Little Lake—*Great Lake.*

To face page 20.]

6. Arthur Lakes Area.

These lakes lie in a broad, flat plain at an elevation of 3090 feet, and separated from the Lake Sorell plain by Alma Tier (3500 feet). At the head of the plain stands Brady's Lookout (4497 feet), and high tiers surround the lakes, except for a small space to the north and a wider opening to the south. The Sandbanks Tier (3500 feet) separates this area from the Great Lake district to the west, and a second ridge runs southwards round the east and south-east of the area through Mount Patrick to Mount Penny (3792 feet). The plain feature extends southwards over St. Patrick's Plains, The Steppes, Lagoon of Islands, and Lake Leacock, and disappears without further elevation in the valley of the Shannon.

A considerable quantity of Ross sandstone occurs over the site of the southern Arthur Lake, in the valley of the Lake River, and westward under and round the southern end of Sandbanks Tier, to the western shore of the Great Lake. Basalt covers much of St. Patrick's Plain and the eastern slope of Barren Tier. On the north-eastern slopes of the lastmentioned feature, overlooking the Great Lake, there are outcrops of Tertiary river conglomerates. Ilmenite sands occur on the floor of Arthur Lakes.

It is probable that the whole of this area was covered by ice during the ice age, but I have not traced direct evidence south of a line between Mount Penny and the southern end of the south Arthur Lake. Northward of this line the evidence is plentiful. The ridges south of Brady's Lookout have been swept clear of loose boulders, and glacial erratics are common over the surface of the plain. Little Lake, to the north of Arthur Lakes, and only 100 feet higher in altitude, lies in terminal moraine country, and the shallow valley through which its overflow reaches Arthur Lake is strewn thickly with erratics of both dolerite and sandstone. Similar, although less plentiful, evidence exists in the area of the plain through which Tumbledown Creek flows, on the neck of land between the two Arthur Lakes, and in extensive fields bordering Sandbanks Tier on the south-east. It is probable that the Arthur Lakes are dammed by morainal material, although I cannot assert this with any degree of certainty. The more prominent ridges of the tiers and larger hills show the typical shattering effect of intense nivation due to protrusion from the ice as nunataks.

The ice appears to have accumulated on the slopes of the flanking ridges, and to have moved in a broad shallow sheet southwards and south-eastward over the area. In a few isolated places it moved northwards and fell over the edge of the plateau. I have not determined the maximum extension. It is possible that ice covered in one sheet the whole area southward to the Steppes, Lagoon of Islands, and the edge of the Shannon valley. If this eventually is proved to have been the case, the more obvious occurrence over the site of the Arthur Lakes would represent a subsequent phase. The area around Little Lake was certainly subjected either to a further phase or, more probably, a much later and more prolonged glaciation than the Arthur Lakes area. The evidence of these phases is very uncertain in this vicinity, and considerably more field work is necessary before a definite statement is possible.

The Lake River has eroded a tremendous gorge as it passes over the edge of the plateau. This has cut southward considerably in post-glacial times, and has removed much of the glaciated landscape just where the vital evidence of terminal moraines might have been expected. A depth of 200 feet has been eroded since the glaciation of the area immediately south of the Arthur Lakes. Incidentally, it may be pointed out that the Lake River has captured the drainage of the Arthur Lakes and Lake Leacock which originally flowed via the Lagoon of Islands and Blackman River to the Shannon. This capture appears to have occurred in post-glacial times, and is due to the considerably greater fall and, hence, cutting power of the Lake River as it passes over the edge of the tiers. There is also evidence of drainage from the south Arthur Lake to the Shannon in the vicinity of St. Patrick's Plains. This may be referable to an interglacial epoch prior to the formation of the lakes and the outlet via Lake Leacock.

7. The Great Lake Area.

This district lies to the west of the one previously described, and is separated from the Arthur Lakes plain by the Sandbanks Tier. It may be considered as a broad, flat valley which is mostly occupied by the Great Lake, 60 square miles in area, and, prior to the building of the Miena dam, averaging only 12 feet in depth, with very few places exceeding 20 feet (Legge, 1904). The plain is bounded on the east by the Sandbanks Tier, on the north by the

P. and P. Roy. Soc. Tas., 1932. Plate X.

[*A. N. Lewis, Photo.*

V. Glacial Erratics on shore of Shannon Lagoon, below Miena Dam—*Great Lake.*

[*A. N. Lewis. Photo.*

VI. Basalt at "The Battery"—*Great Lake.*

To face page 22.]

raised edge of the plateau, Sandbanks Tier joining to the high country south of Mount Tabletop and Mount Projection, these features themselves being portion of the Dry Bluff mass. To the north-west the elevated country is continued as Bastion Bluff, and to the west Split Rock Range runs southerly for some 10 miles. To the south-west the Great Lake plain merges into the Ouse plain, and to the south it is bounded by Barren Tier, which has been cut through by the Shannon River. The surface of the lake is 3333 feet above sea-level, and the surrounding ridges average 4000 feet. The physiographic features of the lake have been very fully described (Legge, 1902, 1903, 1904). The rocks represented are dolerite over the northern portion, Ross sandstone merging into felspathic sandstone over the central portion of the southern lake, basalt covering the plain drained by the Ouse south of Liaweene, and appearing at the Beehives and the Battery on the shores of the Great Lake, with dolerite again at the Shannon outlet.

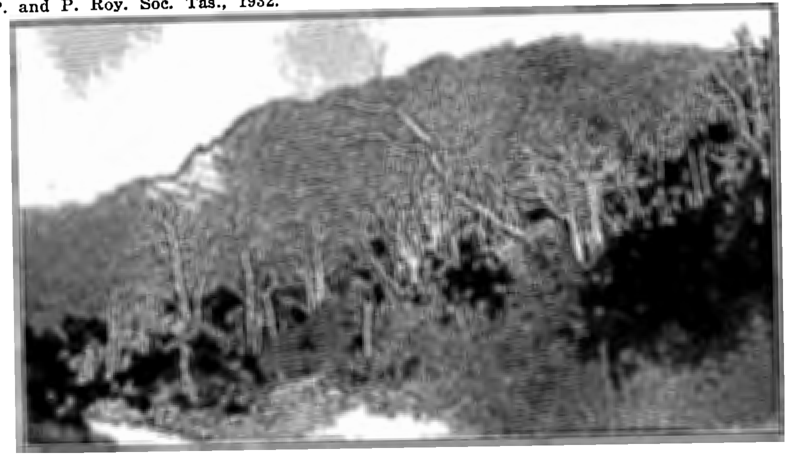
On the edge of the tiers, at an elevation of 4000 feet alongside the Deloraine-Great Lake road, is Pine Lake, a typical mountain tarn, lying in flat terminal moraine country. Small ice-flows, moving southward, coalesced over the site of the lake during the last phase of the ice age. A little further north the Liffey, a tributary of the Meander, has cut an awe-inspiring gorge, as it flows over the edge of the plateau. This has removed much of the glaciated surface between Dry Bluff and Mount Projection by headward erosion. A major fault appears to traverse the length of the Liffey Gorge, and this probably runs southward via Half-Moon Marsh, across the site of the Great Lake and down the Shannon Valley, thence in the direction of the present pipe-line to the Ouse Valley, in the vicinity of Waddamana. However, the statement that this is one fault is at present only assumption. The overflow from Pine Lake, known as Breton Rivulet, crosses flat moraine-covered country for a mile or so, then drops over an eroded rudimentary cirque wall for 300 feet to Half-Moon Marsh. This latter is a typical glacial valley, and ice passed thence over the present floor of the Great Lake. Traces of glaciation descending in a south-easterly direction to join the lastmentioned flow are to be seen in Mickey's Marsh, half-way between Pine Lake and the Little Lake.

The Little Lake and the north-western section of the Great Lake are bounded by a series of small, and not very distinct, cirques. More distinct evidence of glaciation occurs at the north-eastern corner of the Great Lake, and it appears that the main ice-flow passed south-westward from the high country south of Dry Bluff, and coalesced with the other flows mentioned in the vicinity of the centre of the northern half of the Great Lake. A distinct bar separates the northern from the southern portion of the Great Lake (Legge, 1904). At the period of maximum glaciation, ice probably covered this, and coalesced with flows from the Ouse valley and from Sandbanks Tier, to be described next. At a later stage this northern flow probably terminated as a stationary sheet just north of Reynolds' Neck while ice from Sandbanks Tier still existed, also as a stationary sheet, over the southern portion of the lake.

The southern shore of the Great Lake presents features worthy of special mention. In the first place, most of the dissected plain extending from the Pine and Ouse Rivers to Sandbanks Tier, south of the Split Rock, is covered by a sheet of olivine basalt, through which dolerite hills rise as islands, e.g., Murderer's Hill. The basalt country is very easily distinguished by its mild topography. A ridge of this rock extends as a peninsula for 3 miles into the waters of the lake, and terminates in the Beehives. After being submerged opposite the mouth of the Shannon it appears again towards Todd's Corner, at the Battery, and thence extends southwards over the shoulder of Barren Tier. The valley southward of this ridge is drowned by the waters of the lake, and is known as Swan Bay to the west and Todd's Corner to the east. The next ridge to the south forms the shore of the lake, and consists of a line of dolerite kopjes. Further southward again is another more or less parallel valley, occupied in its lower portion by the Shannon Lagoon. Then Barren Tier terminates the Great Lake plain by a third parallel ridge. The features mentioned are primarily due to erosion, as is shown by the fact that the basalt ridge at the Beehives appears at the Battery as a continuation of the dolerite ridge, with which it makes one physiographical feature in the latter locality.

The Shannon cuts through the dolerite ridge at the site of the Miena dam, the keystone of Tasmania's industrial activity. When the foundations for this structure were being excavated the dolerite was found to be seamed with wide bands of weathered rock, which isolated seemingly solid surface outcrops as large floating boulders. This was more marked on the banks than in the bed of the Shannon, which appears to have removed the weathered material. Dr.

P. and P. Roy. Soc. Tas., 1932. Plate XI.



[*A. N. Lewis*, *Photo.*

VII. Edge of Dolerite Sill. *Mt. Projection, Western Tiers,* from Deloraine-Great Lake road.

[*A. N. Lewis*, *Photo.*

VIII. Moraine at *Pine Lake,* north of Great Lake.

To face page 24.]

Loftus Hills informed me after his inspection that the appearance was that of dolerite weathered *in situ*, and no suggestion that the bar was a glacial moraine could be found.

However, the valley south of the dam shows unmistakable evidence of glaciation. Erratics cover it sparsely from the Sandbanks Tier, across Todd's Corner, right to the Shannon Lagoon, and a few may be found on the west shore of the latter and in the valley leading to it from the south-west. At some stage ice passed down the Shannon, at least to the intake of the canal leading to the Shannon power-house, and probably further.

My explanation of the southern shore of the Great Lake is this. During the maximum extension of the ice age a large shallow ice-sheet covered the whole valley, and met the ice-sheet in the Arthur Lakes valley. Later, for a long period during the recession of this phase, smaller ice-sheets covered (1) the southern Great Lake to a depth of about 50 feet above the present water-level, deriving their source from Sandbanks Tier, the Ouse, and south of Murderer's Hill (this banked up against the northern slope of the dolerite ridge at approximately the present shore line of the lake); (2) immediately to the south a smaller ice-sheet, deriving its source from Sandbanks Tier and Barrier Tier, banking up against the latter. The Shannon gorge between the Lagoon and the Shannon power-house is, in its present configuration, definitely lower and wider than when the ice-sheets covered the area stated, although no evidence is at present forthcoming as to whether it is post-glacial entirely.

The dolerite bar and line of kopjes that now limit the southern shore of the Great Lake were eroded as a long razor-backed nunatak between these ice-sheets. It probably only protruded 50 feet at its eastern half from the ice, although the top of the ice over the Shannon Lagoon appears to have been some 50 feet lower than that over the Great Lake. It is possible that the Great Lake once drained to the Lagoon via Todd's Corner, and that the Shannon outlet at Miena was more recently eroded.

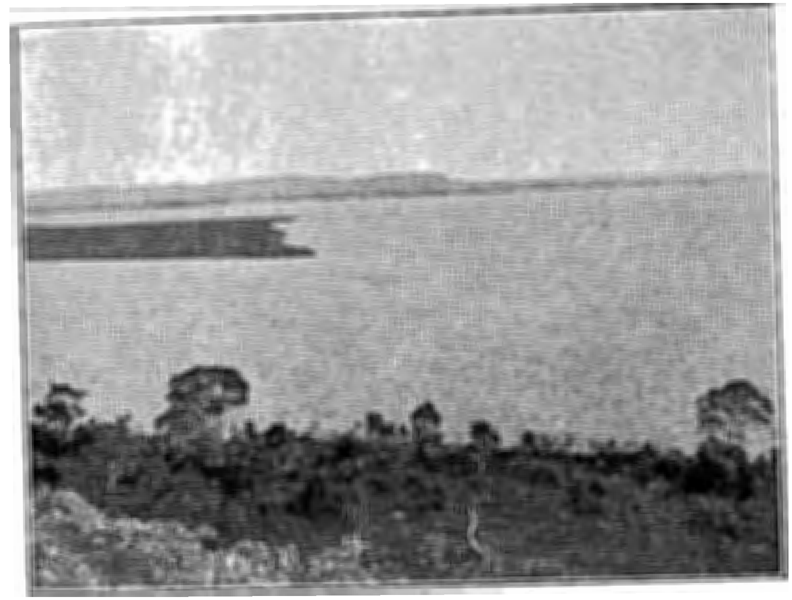
8. The Nineteen Lagoons - Ouse - Pine River Area.

The country between Mount Ironstone on the north-west, the Great Lake on the east, and the Pine River on the south-west, may be considered as the next geographical area, although no definite western boundary can be fixed. This is a bare, desolate moorland of rocky ridges, lagoons, and swamps, difficult of access, and snow-covered during most of the year. To the north the edge of the Western Tiers rises in a long ridge (Bastian Bluff, 4400 feet, and Mount Ironstone, 4700 feet). Thence the land drops rapidly in talus-covered terraces to about 3700 feet, and then in a gently sloping plain for 20 miles, with a general south-easterly drainage to the gorges of the Ouse and Pine on the southern edge of the plateau. Near the middle of the plain a considerable nunatak ridge, the Little Split Rock, stands over Lake Augusta. South of this feature the valleys of the rivers mentioned and their many tributaries are more marked, and are separated by typically nunatak ridges of shattered dolerite, running generally south-east.

The whole of this area is intensely glaciated at least as far south as a line from Swan Bay to Lake Fergus, and I think, although the evidence is very slight, that ice at its maximum extension descended to the Skittleball Plains at least. At this period it probably coalesced with the ice of the Great Lake area across the plain between the Split Rock and Barren Tier. Much of the southern slopes of this area are covered by basalt, and consideration must be given to the different way in which this rock and the islands of dolerite protruding through it have been affected by weathering. It is easy, at first sight, to picture the topography of the basalt as due to ice, and that of the dolerite ridges as due to frost, action on the rock protruding through the ice-sheets, but the close association of rock type with topographical forms gives a warning that these differences may be due to normal weathering alone. For this reason, if it were not for the conclusive evidence of surrounding districts, I would hesitate to say that these basalt plains had been affected by ice. However, from the fact that ice did cover surrounding localities, and that basalt flows occurring on lower levels—for example, at Bashan—do not exhibit the appearance of an ice-cap topography, it is probable the plains between the Great Lake and the Skittleballs were covered by ice. Possibly the level, smoothed-out topography was due originally to pre-glacial erosion of the softer rock, and this induced an accumulation of ice during the ice age over the basalt, while the dolerite protruded as nunataks and ridges too steep for the snow to lie on. The ridge between Swan Bay and the Ouse, and that between the Ouse and the Little Pine Rivers, overlooking the Skittleballs, certainly show many small and rudimentary cirque features, and Lake Fergus is definitely of glacial origin. It is very probable that ice at some time

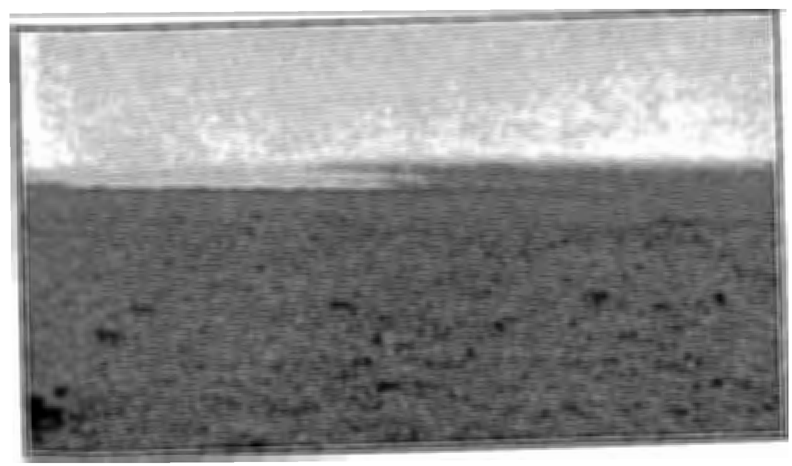
P. and P. Roy. Soc. Tas., 1932.

Plate XII.



[*J. W. Beattie, Photo.*

IX. *The Great Lake*, looking north from Miena, over Swan Bay and Beehives, to Split Rock.



[*A. N. Lewis, Photo.*

X. Most southerly of the Nineteen Lagoons, showing morainal dam.

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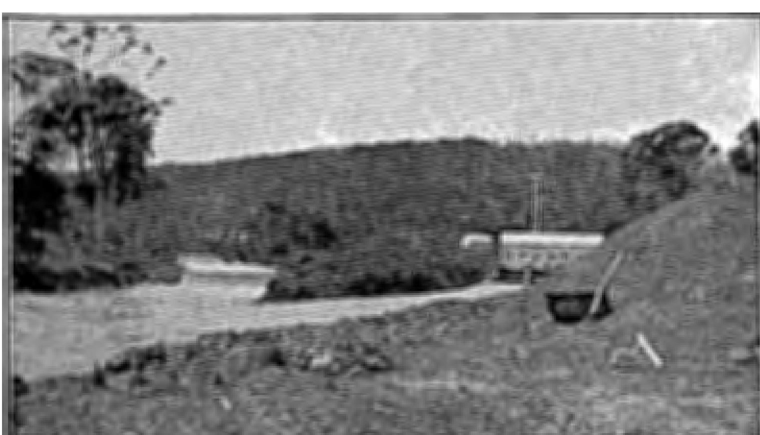
[*J. W. Beattie, Photo.*

XI. Gorge of *River Ouse* at Liaweene, showing extent of post-glacial erosion.



[*A. N. Lewis, Photo.*

XII. Gorge of *Shannon River* through Barren Tier.
Shannon power-house in foreground. Drop of pipe-line (290 ft.) shows depth to which Shannon has cut in under 5 miles.

To face page 26.]

passed over the site of the Ouse bridge on the " Missing-link " track, and thence debouched on to the Skittleballs. Here, the post-glacial erosion appears to have been comparatively slight—not 50 feet in depth.

A little further north the effect of ice movement is more apparent. Here the sheet was divided for long distances by low parallel dolerite ridges, and some morainal deposits are apparent. A clear one exists in the valley of the Armytage Rivulet, due west of the Ouse bridge at Liaweene. Thence northward to the Nineteen Lagoon area the country is certainly, although indistinctly, a huge terminal moraine area, and Lake Augusta, with its surrounding lagoons and swamps, is the result of the indeterminate drainage typical of such topography.

This glaciation becomes more and more obvious as you proceed northward. On the flanks of Mount Ironstone are many mountain tarns, such as Lake Meander, Lake Ironstone, Lake Lucy Long, and others. These are impounded behind typical valley glacial moraines. Moreover, they represent a later phase distinct from and covering the morainal deposits of the Nineteen Lagoon country. Opportunity has not occurred for me to investigate in sufficient detail the evidences of superimposition of actual moraines, but Dr. Loftus Hills has informed me of the existence of strong evidence of a definite inter-glacial epoch between moraines in the vicinity of the head waters of the Fisher River, and this locality should be productive of most important results when time can be found to explore the moraines in the necessary detail.

9. Lake Echo Area.

Lake Echo presents one of those difficult contradictions which, nevertheless, afford the clue to the whole problem. It lies well south of what might otherwise be considered the glaciated area, and is entirely cut off from the Great Lake and Ouse valley glaciations by river-eroded valleys. Its height (2717 feet) is somewhat less than that of the lowest locality in which glaciated topography can be identified with certainty in the northern areas. Nevertheless its origin must be identical with that of the other large lakes of the plateau. In fact, its basin is glaciated, and the surrounding valleys have been eroded subsequently. It appears, therefore, to represent a residual portion of the plateau as it existed at the time of the maximum extension of the ice-sheet.

The lake is enclosed in a circle of hills, rising to about 3500 feet to the north-west and 3000 to the south. It is also a shallow sheet, 20 feet depth being exceptional. North of the lake are considerable plains which appear to be portion of the same feature, now drained by tributaries of the Ouse, the valley of which has cut into them. Ice moved southward across this plain, over a low saddle, and into the north-east corner of the lake. Smaller flows moved south-eastward from the high ridges known as The Tops, lying between the lake and the Nive valley. These coalesced over the present site of the lake. The lake is at present dammed by a dolerite bar, through which the Dee is cutting. To the north-east of this, and extending to the basalt flows at Bashan, is an outcrop of sandstone. Ice seems to have passed across the present mouth of the Dee, and the dolerite here is either shattered by nivation or lightly covered by moraine, probably the latter. The valley of the Dee near the lake is covered by luxuriant vegetation of typically western flora, and this effectually obscures the evidence of morainal deposits. Post-glacial erosion does not appear to have reached the lake-level.

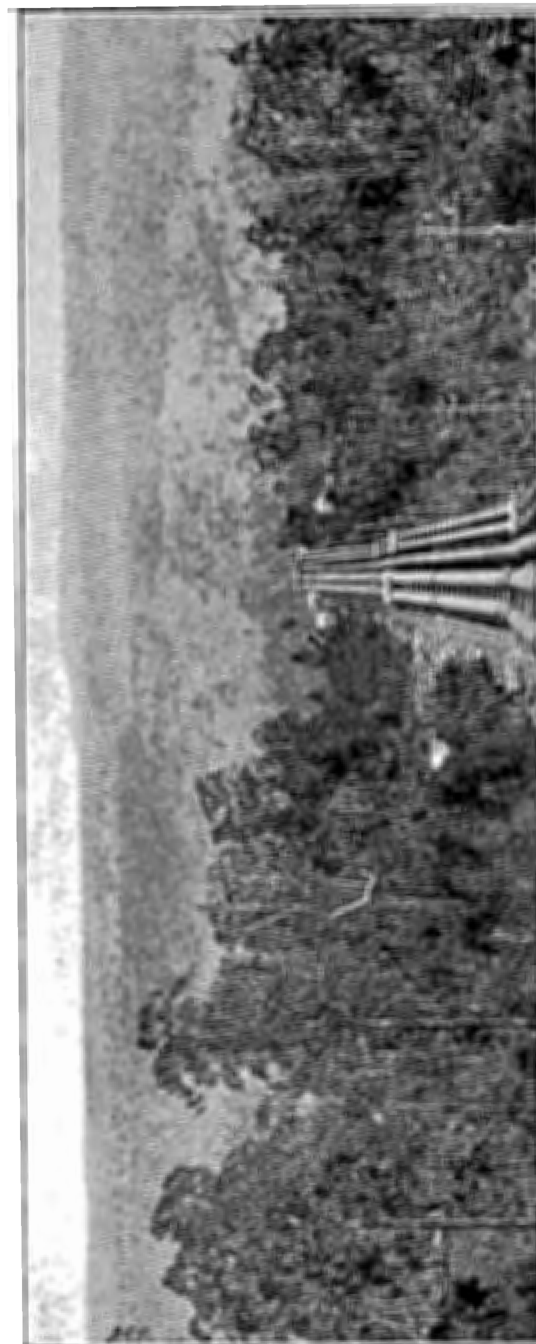
In this vicinity, and between here and Lake St. Clair, there are numerous valleys that have the appearance of more or less drained lakes—for example, Victoria Valley and Bashan Plains. Mike Howe's Marsh, in the valley of the Blackman River, east of Lake Sorell, is another example of this feature, and the Lagoon of Islands and Lake Crescent afford examples of the connecting links between these marshes and the shallow lakes. I have not yet discovered, however, any trace of glacial action south or east of Lake Echo, or lower than 2700 feet west of the Nive River, and these features are probably due to recent earth movements, with or without the interposition of the effects of ice.

10. The Ninety-Nine Lagoons Area.

Westward of the Pine River catchment, and stretching thence to the dissected western edge of the plateau, is a district well named the Ninety-nine Lagoons, although probably ten times that number of lakelets exist. Here the acreage covered by water may exceed that which is dry. The head waters of the Mersey and Forth, and their many tributaries flowing north, have cut deeply into the original plateau surface, and the Nive and Clarence, flowing south, have also eroded considerable areas, although not nearly

P. and P. Roy. Soc. Tas., 1932.

Plate XIV.



XIII. Gorge of *Ouse* at Waddamana.

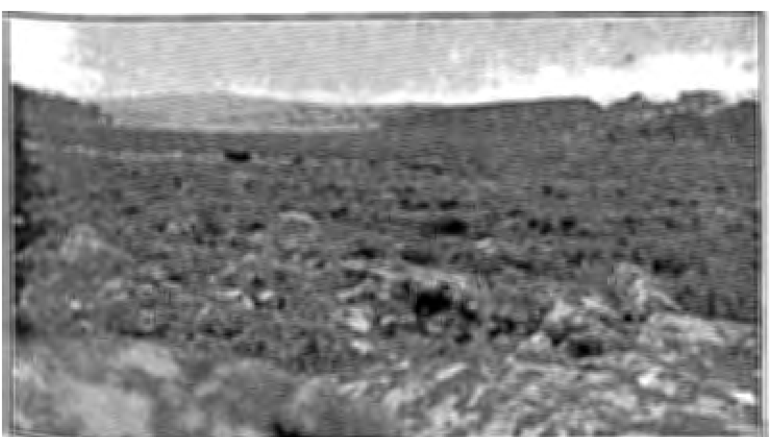
[J. W. Beattie, *Photo.*

Power-station is on bed of river, 1200 feet below spot where pipes disappear. Uneroded plateau covered by basalt lava flows, and either glaciated or slightly affected by near proximity of glacial conditions, in background.

[To face page 28.]

[A. N. Lewis, Photo.

XIV. *Lake Echo,* looking south.



[A. N. Lewis, Photo.

XV. Glaciated Valley immediately north of Lake Echo.

To face page 28.]

to the extent of the northern rivers. The district is very flat, and to the north entirely covered by terminal moraine deposits, amongst which the lakelets lie. To the south the country is similar, but is traversed by long, low, parallel nunatakal ridges of shattered dolerite. A few outstanding mountains protrude, such as Culmar Bluff and the China Wall. These show typical nunatak features. I have not investigated this area in detail, but it appears that the ice responsible for the topography moved south-eastward from névé fields in the Barn Bluff, Pelion, and Du Cane Ranges, and is referable to the last phase of the ice age.

The Mersey, Forth, Nive, and Clarence have eroded much of the glaciated country, and the present features of these valleys are certainly post-glacial. They have not, however, entirely removed the glaciated plateau at their head. Both the Forth and the Mersey are working down fault-lines or zones. There appears to be a distinct break in the geology of the plateau from a general line through the Forth valley, and continued southward. Mr. McIntosh Reid's mapping indicates that westward of this line the elevation has been more considerable and, it seems to me, from the amount of erosion, earlier. Sedimentary rocks, pre-Cambrian schists, Permo-Carboniferous series, and Ross sandstones, &c., are to be found at 4000 feet, and are far more common than is the case further east. The dolerite appears as an elevated and thoroughly dissected sill.

11. The Western Ranges.

These have been fully described, as before mentioned, and I have no further data regarding this portion of the plateau. I merely desire to point out that these ranges must be considered as part of the Central Plateau. Their physiography has been determined by similar influences, although here these influences have been more intense. The main valley features and the dissection of the plateau were largely completed in pre-glacial times. Thus the ice was accorded fields on which to accumulate and valleys through which typical valley glaciers could move. These features, and their absence further east, are sufficient to account for the difference in the glacial forms now apparent. Also, the precipitation was considerably greater on the west of the plateau, and thus the ice was enabled to reach lower levels. Ice certainly descended to 2300 feet at Lake St. Clair, and perhaps it reached as low as 2000 feet. The country in the vicinity of the Clarence Lagoons, and that crossed by the West Coast-road in the Clarence Valley and westward to the Derwent, shows evidence of glaciation during an early phase. The Derwent has eroded its valley to within 10 miles of Lake St. Clair very considerably since glacial times, and many possible traces of the lower limits of ice movements have been removed.

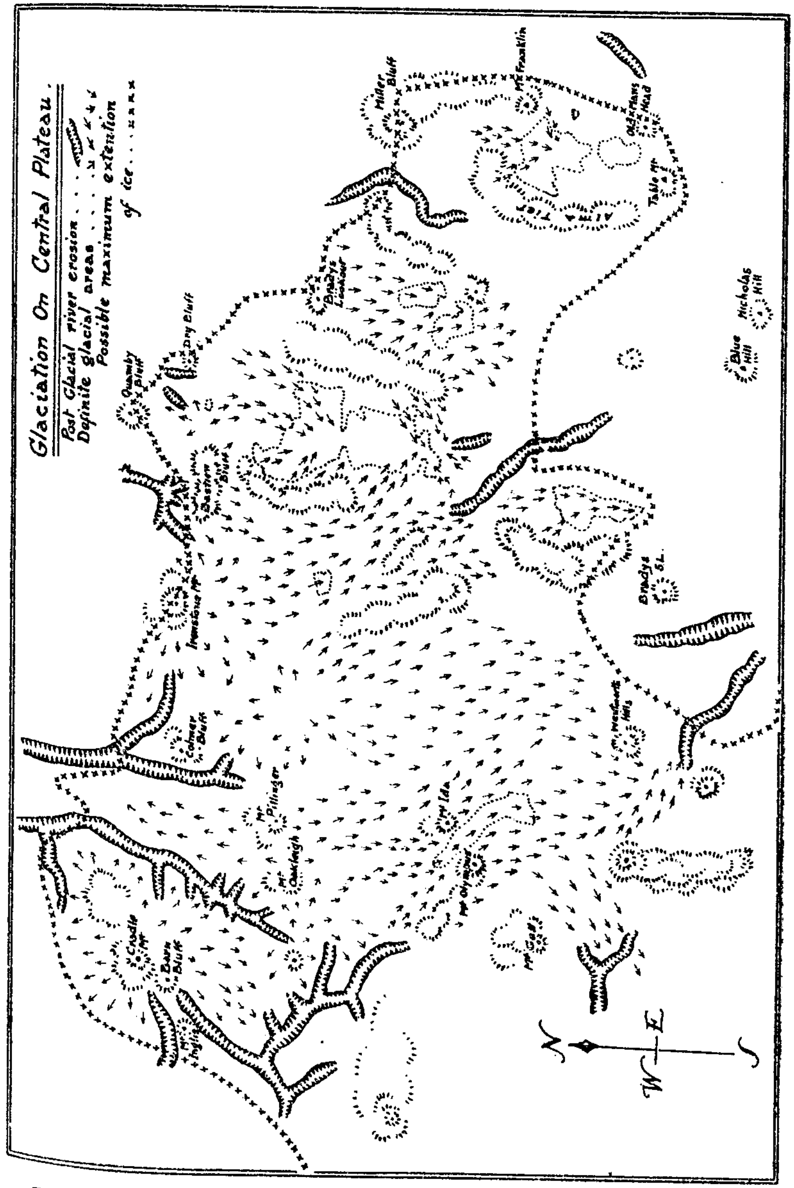
12. Pleistocene Glaciation on the Central Plateau.

To summarise the conclusions forced by the field evidence noted above, it is sufficient to say that the plateau surface, as existing in Pleistocene times, was subject to intense glaciation in its north-western quarter, and thence the ice-sheet became thinner and finally broken into small occurrences. The whole plateau above 2800 feet was within the permanent snow-line during the most intense epoch. Except towards the west, the ice took the form of a fairly stationary ice-sheet, and the typical features of valley glaciation could only develop in a few localities. In consequence of the flat topography and the hard dolerite, little erosion was effected, and, from the same cause, morainal deposits are few. The erosion forms are mostly those of a typical ice-sheet. Post-glacial erosion in the river valleys has removed the traces of valley glaciation if such ever occurred. On the higher levels the ice-cap eroded considerable and frequent hollows by nivation when stationary during the recession period. There is distinct evidence of two phases and indications of a third and more extensive phase. The last phase appears to be superimposed on the earlier one, and the terrain presents great possibilities for the further study of this vital problem when the opportunity presents itself.

It must be borne in mind that the present-day conditions over the plateau are severe. During the winter of 1920-21, when the Great Lake construction works were in full swing, football matches were played on the ice of the lake. The winter snowfalls of the present time are sufficient to account for the treelessness of the higher plains, and ice in modern times has piled up shingle terraces round the lakes (Legge, 1902). Conditions similar to these must have existed at considerably lower elevations during the ice age. This and the ice-cap conditions during the maximum phase of the ice age, and the extent of post-glacial erosion, make it very difficult to say with certainty what was the limit of the ice-cap of the plateau. I have no hesitation, how-

P. and P. Roy. Soc. Tas., 1932.

Plate XVI.



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ever, in saying that the country north of a line from Mount Charles to Table Mountain was affected, during the Pleistocene, if not by permanent ice, certainly by heavy winter snowfalls.

The ice-cap was never very thick; perhaps 100 feet was its maximum in the eastern half of the plateau. It covered pre-glacial plains, and all the then existing hills and prominences protruded as nunataks of bare rock. Most of this rock was dolerite, which is seamed with cooling cracks. The intense frost action, and the effect of heating during the day and freezing during the night, shattered this exposed rock, and gave us the typical hill features of this area, namely, a general appearance of vast accumulations of loose boulders.

The remarkably clear glacial topography made easily accessible by the West Coast-road clearly shows that, during the maximum phase of the Pleistocene ice age, the whole of the country from the Great Lake to the sea was covered by ice, except where mountains protruded. Evidence at present to hand points to a coalescence of a multitude of mountain glaciers into a more or less stationary ice-mass completely filling the valley and plain areas. The apparent gaps in this sheet in many places, as in the lower valleys of the King and Gordon and Derwent Rivers, are due to post-glacial erosion. This has effected a modification of the physiography of Western Tasmania to an extent not hitherto appreciated, and points to considerable uplift and rejuvenation by the river systems between the maximum phase and the most recent mountain tarn phase of the ice epoch which has been responsible for the more apparent moraines.

13. Post-Glacial River Erosion.

The degree to which the rivers draining the plateau have cut into the glaciated surface of the original uplift has surprised me. This has not occurred materially in regard to the most recent morainal deposits, but the evidences of the earlier, and most extensive, glaciation have been largely removed. This forces the inquiry, whether the glaciated area of many of our other plateaux has not been greatly underestimated, and whether we have not been missing the identification of the lower limits of the Pleistocene ice-sheets by reason of subsequent erosion. This, in its turn, emphasises the importance of fuller investigation of glaciation at lower levels as occurring on the West Coast.

Commencing with the Ouse Valley, we see, at Waddamana, a gorge 1200 feet deep cut in the original plateau surface, which has also been thoroughly dissected by small tributary valleys of the Ouse. The remnant of the plateau above these valleys shows evidence of having been affected either by an ice-sheet or by severe snow conditions approaching those of permanent ice. Such topography crosses the Shannon and Lake Echo depressions, and the Ouse has eroded either its whole gorge, or substantially so, since the period of the maximum extension of the ice. This river has, by headward erosion, cut right into the moraine-covered plateau surface as far north as Lake Augusta. Opposite Swan Bay it has cut about 200 feet into the plateau since the maximum phase of the glaciation, and this is true for some 5 miles northward to the gorge north of the Ouse Canal at Liaweene.

The latter phases of the glaciation occupied this valley to about a mile north of Liaweene and further south in the Pine River and tributaries of the Ouse. The Ouse itself has cut about 50 feet into its valley as shaped by this last phase, but, owing to control by dolerite bars, much of the glacial topography in the upper portion remains.

The Shannon from the power-house to the Lagoon shows a smaller, but similar, gorge cut, or very considerably deepened, since the ice receded from the Greak Lake. This has cut at least 200 feet in dolerite in post-glacial times. The Dee and Nive have also cut considerable, although lesser, gorges in the glaciated surface of the plateau. It is apparent that the ice has considerably interfered with the normal sequence of river erosion. I cannot at present throw any light on the pre-glacial drainage. It is possible that, at some stage, the Great Lake drained into the Ouse, and thence, via the Skittleballs, into the Nive; but this is uncertain. The Shannon to a lesser extent, and the Ouse to a greater extent, have been active, in recent times, in capturing drainage from surrounding streams. The gorges of these rivers are of very recent extension into the plateau, and the Ouse has certainly captured much of the drainage of the Nive, and may shortly behead the Little Pine River, &c., at the Skittleballs.

A factor that is apparent in the upper portion of the Ouse, and which I have observed elsewhere, is that a stream will frequently erode round the side of an ice-filled valley, and a large glacier in the main valley will protect the

[*Spurling, Photo.*

XVI. Edge of Dolerite Sill—Valley of Fisher River.
Showing glaciated plateau above and post-glacial erosion of Mersey drainage system.

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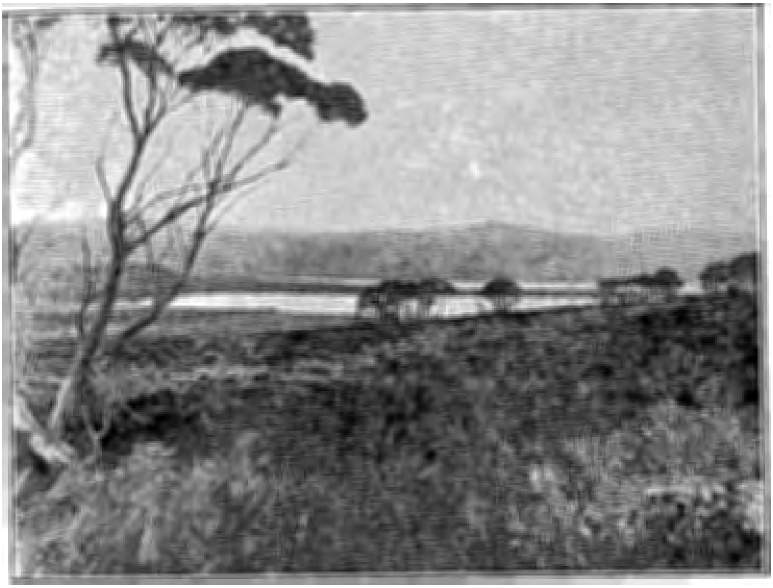


[*J. C. Breadon, Photo.*

XVII. *Lakes Sandy Beach and McKenzie*, under Mount Ironstone.
Note moraine in foreground, and also separating lakes.

[*Spurling, Photo.*

XVIII. *Mount Ironstone* and glacial lakes in vicinity.

To face page 32.]

terrain from erosion when a stream in a smaller adjacent valley is wearing down a bed below that of the ice-filled principal valley. After the disappearance of the ice these streams capture the drainage of the main valleys. It is, therefore, frequently found that the main drainage course of to-day was not the main valley in pre-glacial times nor the site of the largest glacier.

The northward flowing rivers, Forth, Mersey, Meander, Liffey, and Lake, have cut far deeper and more spectacular gorges, having reached soft sedimentary rocks below the dolerite (as is also the case with the Ouse). Their shorter and steeper slopes have enabled them to do this. But, at the same time, as they are cutting into the highest portion of the plateau, they have interfered less with the glaciated surface. In spite of this, river erosion has proceeded in all these cases to a very considerable extent since glacial times, perhaps to the depth of 2000 feet since the time of the maximum extension of the ice. All these questions of erosion are very uncertain, as evidences of valley glaciers in the gorges mentioned have been entirely removed.

14. Older Peneplain of the Derwent Valley.

Mr. Clemes has drawn attention to the existence of a lower plateau extending from Lake St. Clair to Lake Echo at an elevation of some 2500 feet (Clemes, 1924). This is so, but it extends far beyond the eastern boundary assigned by Mr. Clemes, and may be regarded as the same feature as the Oatlands spur of the plateau described by Mr. Nye (Nye, 1921). From Hamilton northward to the Steppes, north-westward to Lake St. Clair, north-eastward and eastward to Oatlands, Tunnack, and Colebrook, there is evidence of a dissected peneplain. This exists now as mere flat-topped residuals between wide valleys, and appears to have been uplifted in a series of step-faults to the upper levels of the Central Plateau. It corresponds with the Midlands in general, but is much more deeply cut by the river valleys. The general trend lines of the main uplift on the southern boundary of the plateau are not as clear as on the other sides, and the possibility of a partial subsidence, although not to the original level, must not be ignored. In fact, the uplift of the Central Plateau appears to have occurred by segments at different stages and to different heights, thus further complicating the deciphering of the physiographical influences.

15. Origin of the Great Lake and Other Lakes on the Central Plateau.

As has been sufficiently indicated, the origin of all the lakes, except the Great Lake, Lake Echo, Arthur Lakes, Lake Sorell, and Lake Crescent, is definitely due to glacial action, and they in nowise differ from the mountain lakes and tarns of the western ranges. The only doubt exists as to the large lakes above named. It is certainly a difficult problem, and the evidence is not very obvious. The theory that they are due to original hollows in the dolerite must be discarded in view of the time that has elapsed since this rock first appeared, and the theory that they are due to inequal erosion of overlying sandstone is not sufficient to account for all the physiographic features surrounding these lakes. If there were no possibility of ice action, of course, another explanation would have to be sought, and previous opinions proceeded on this assumption. I have presented, I hope, enough evidence to show that the whole area was subject to ice action to a greater or less extent, and therefore the obvious cause was actually in operation.

The lake basins in question have certain features in common. All except Lake Echo appear as two sheets, connected to a greater or less extent. In every case sandstone and basalt occur towards the overflow side, while the upper sides are shallow cirque-like depressions in the dolerite. These factors are common elsewhere, and therefore may be mere coincidents. The lakes are all extremely shallow for their area. This must be largely due to post-glacial deposition, particularly of diatomaceous mud, but the original flatness of the plains in which they lie is obvious. More important is the factor that in every case there occurs a considerable hill or tier on the outlet side, and the lakes lie over the site of the coalescence of two or more ice-flows, of which one or more moved to some extent against the general direction of the movement of the major flows. None of these lakes is dammed by a moraine, although morainal deposits occur to some degree near the outlet of all except Lakes Sorell and Crescent. It is clear, from evidence in the Midlands, that, although a river cannot erode a lake basin in the normal course of erosion, where a small creek suffering from floods cuts from a sandstone area through a bar of dolerite, it sometimes erodes the sandstone behind the bar to form a swamp which will flood into a lake. Add an invasion of ice to such an area, and the swamp could be

[*Spurling, Photo.*

XIX. Ouse-Mersey Watershed.
Lake in foreground drains north, lake in background drains south.
Note ice-cap topography.

[*Spurling, Photo.*

XX. Glacial Topography at head of Nive River, in the Ninety-nine Lagoon Country.

To face page 34.]

deepened sufficiently to form a basin such as is now occupied by the large lakes of the plateau. It is not absolutely clear, however, that such a simple explanation, which is a possibility, is actually the whole story of the development of these lakes.

In my opinion, these large lakes occupy hollows which represent the final sites of small ice-sheets, the last remnants of larger sheets which imparted the typical ice-cap topography to the plains in which the lakes lie. During the recession period the ice became confined to certain localities, and here eroded slight depressions by nivation.

At the same time, the whole of Tasmania is rising at the present time, and this has continued since Pleistocene times, allowing for the more rapid rise of the sea-level during a comparatively short space of time. The valleys of all the streams show slight recent uplift, and this is particularly plain in the valleys of the Dee and Nive. It is quite possible that this gentle uplift has been sufficient to cause an interruption to the drainage in the flat glacial plains, and I think that this influence has been partly responsible for the present existence of these lakes. I do not think that we would have had the lakes if it had not been for the effects of Pleistocene glaciation on the plateau topography, but the proximate cause appears to have been the slight earth movements operating on the ice-sheet topography.

16. Geology of the Hydro-Electric Scheme.

Sufficient description has been given of the terrain of these works, and it is only necessary to summarise the conclusions that all the evidence points to. The foundation of the physiographical influences which have made the scheme possible is the uplift of the plateau in sufficiently recent times to permit the bounding escarpments to persist. This has rendered possible the existence of high-level lakes, and has given the rivers flowing over the edge of the plateau the power to erode deep gorges in close proximity to the storage sites on the higher levels.

The fact of the existence of the Great Lake itself means little to the scheme, but the fact of the wide, flat plain in which it lies is vital as a site for sufficient storage. This, as has been shown, is due, primarily, to erosion by a slowly moving ice-sheet. The slight degree of erosion by this sheet has resulted in the absence of deep morainal deposits which would have gravely militated against the construction of a suitable dam. Thus, glacial action has been the primary factor in making the whole scheme possible.

The next consideration is the fact that the Shannon River has cut through Barren Tier, that the Ouse has also done so, but on a separate and parallel course, and that in so doing the Ouse has eroded its bed to a depth of some 1200 feet below that of the Shannon, and has done so at a spot where the divide between the two rivers does not rise appreciably above the level of the bed of the Shannon.

These factors are due principally to the headward erosion of the rivers mentioned, made possible by the fall imparted by the original uplift. Both rivers have probably found a major fault line or zone. The Shannon at the Shannon power-house flows out on to the original surface of the plateau in this vicinity, and has worked back thence to the Lagoon. The drop is 300 feet in 5 miles. This portion of its course has been eroded into a considerable gorge.

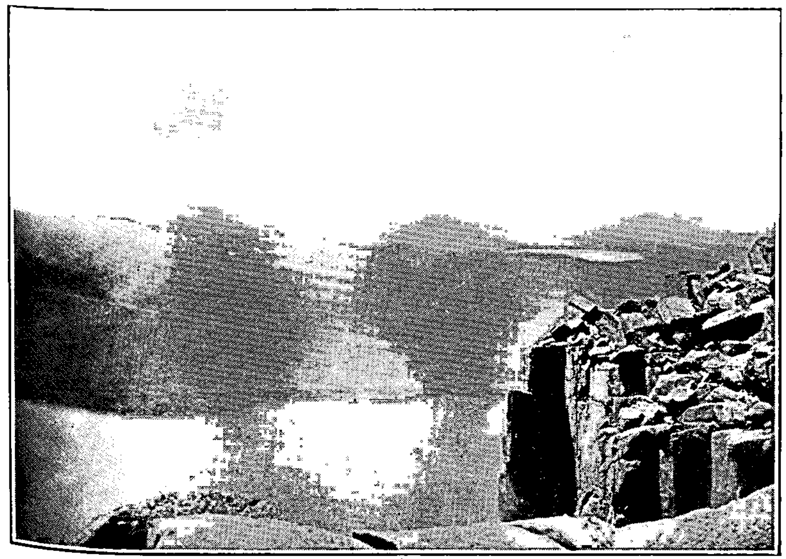
Many factors have contributed together to enable the Ouse to deepen its valley to such an extent below that of the Shannon. Opposite Swan Bay the Ouse is scarcely 100 feet below the level of the Great Lake. Ten miles down its course it is 1200 feet or so below the level of the Shannon. Twenty years ago Mr. Clemes suggested to me that this was due to the fact that the Shannon drained out of a lake, and consequently left it without sediment, and the Ouse, passing round the side of the lake, was able to commence with a considerable sediment load by the time it was opposite the source of the Shannon. My observations confirm this. The Ouse, at the Skittleballs bridge, is moving a considerable shingle load, and undoubtedly this is an important factor. But it is not the only one. The Ouse had, originally, a far greater flow of water, and, from its more westerly situation, its numerous tributaries, its barren catchment area, and the absence of considerable lake barriers in its course, is subjected to violent flooding from which the Shannon was free. More than this, the Ouse has a shorter, and more direct, course from the plateau to its lower junction with the Shannon, and, most important of all, has reached the soft Permo-Carboniferous rocks below the dolerite at a higher elevation than has the Shannon.

Permo-Carboniferous rocks appear in the valley of the Ouse at Waddamana at an elevation of some 400 feet above the present bed of the river, which has considerably deepened its valley in these rocks, while the Shannon is still eroding through the hard dolerite for a much longer distance. The

[*Spurling, Photo.*

XXI. *Rugged Mountain* from Valley of Mersey.

This is a typical nunatak under present Tasmanian conditions, viz., bare rock above, swampy glacial valley below, dense vegetation on talus-covered slope. Rugged Mountain is the most easterly of the residual mountains of the western edge of the plateau.



[*C. E. Lord, Photo.*

XXII. *The Central Plateau,* looking east from Mount Olympus.

Lake St. Clair in the foreground, with Mount Ida beyond. Traveller Rest Lakes in right background, and Mount Ironstone on skyline to left.

To face page 36.]

Ouse found a fault-line in its lower course, and this has enabled it to penetrate the dolerite more easily. The greater angle of slope, its greater volume, and sediment load has enabled it to cut deeper into the plateau wall, and this, in turn, has given it greater power in ascending ratio. To these factors the depth of the Ouse gorge at Waddamana below the Shannon valley is due, and thus the other vital factor of the sufficient fall is present. The pipe-lines from the Shannon diversion follow the original surface of the plateau as it appeared in Pleistocene times. At no great distance in the future the Ouse would have beheaded the Shannon in the vicinity of the transmission-line to Launceston, if it had not previously drained the Great Lake just north of Murderer's Hill, in which vicinity a tributary of the Ouse approaches within half a mile of the shore of the lake at a lower elevation.

17. ACKNOWLEDGMENT.

I acknowledge with gratitude the assistance of Mr. Eric Brock, of Lawrenny, who kindly drove me to the Lake Echo, at the source of the Dee, and thus enabled me to complete this paper; the services of my friend, Mr. F. C. Mitchell, in the field, and in assisting me with the plans accompanying this paper; of Mr. Spurling, for the photographs of the western portions of the area, taken on a trip he made from Mount Ironstone to Lake St. Clair; and of Mr. C. E. Lord and Mr. J. C. Breaden, for other photographs reproduced in the paper.

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